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Niranjayan et al.

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(54) **USER AUTHENTICATION WITH PORTABLE DEVICE AND SMART FLOOR**

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G07C 9/00 (2020.01)

(52) **U.S. Cl.**
CPC ***G07C 9/00071*** (2013.01); *G07C 2209/02* (2013.01)

(58) **Field of Classification Search**
CPC G07C 9/00071; G07C 2209/02
USPC 340/5.52
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,225,980	B2	6/2007	Ku et al.	
7,911,342	B2 *	3/2011	Sekine	G07C 9/00309 340/572.1
7,949,568	B2	5/2011	Fano et al.	
8,009,864	B2	8/2011	Linaker et al.	
8,189,855	B2	5/2012	Opalach et al.	
8,355,992	B1 *	1/2013	Haugh	G07G 3/006 705/64
8,593,672	B2 *	11/2013	Aoyama	G06F 21/34 358/1.13
8,630,924	B2	1/2014	Groenevelt et al.	
9,235,928	B2	1/2016	Medioni et al.	
9,473,747	B2	10/2016	Kobres et al.	
2003/0177102	A1 *	9/2003	Robinson	G06Q 20/04 705/75
2004/0078340	A1 *	4/2004	Evans	G06Q 20/10 705/64
2006/0237427	A1 *	10/2006	Logan	E05B 47/0002 219/401

(Continued)

OTHER PUBLICATIONS

Asthana, et al., "An indoor wireless system for personalized shopping assistance", CiteSeerX, In Proceedings of IEEE Workshop on Mobile Computing Systems and Applications, 1994; [retrieved on Jun. 30, 2013]. Retrieved from the Internet: <URL:http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.127.3033>.

Dietz, et al., "DiamondTouch: A Multi-User Touch Technology", Mitsubishi Electric Research Laboratories. TR2003-125. Oct. 2003. Retrieved from Internet: <<URL: http://www.merl.com/publications/docs/TR2003-125.pdf.>>.

(Continued)

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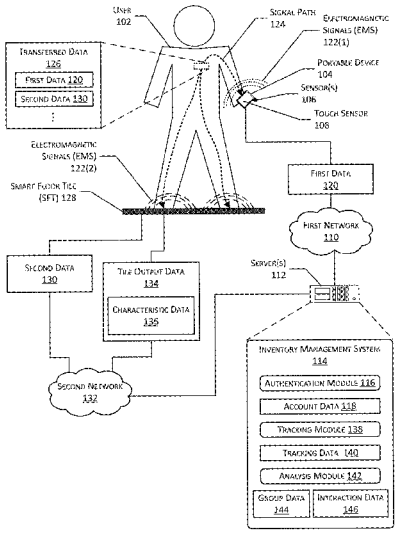
(57) **ABSTRACT**

A user obtains authentication credentials using a portable device, such as a smart phone. While standing on a smart floor in a facility, the portable device transmits the authentication credentials to the smart floor. The body of the user electromagnetically couples to electrodes in a touch sensor of the portable device and one or more antennas of the smart floor, acting as a signal path for signals between the mobile device and the smart floor. For example, one or more of the voltage applied to the electrodes, timing of when voltage is applied, and so forth, may be used to produce a particular electromagnetic signal that conveys the authentication credentials. The authenticated user may now be tracked in the facility using the smart floor.

21 Claims, 12 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0288319	A1*	12/2007	Robinson	G06Q 30/02 705/14.25
2008/0022089	A1*	1/2008	Leedom	H04L 63/068 713/156
2009/0171851	A1*	7/2009	Beenau	G06K 9/00 705/72
2010/0090813	A1*	4/2010	Je	G06F 3/016 340/407.2
2010/0277763	A1*	11/2010	Aoyama	G06F 21/34 358/1.15
2010/0289772	A1*	11/2010	Miller	G06F 3/0421 345/175
2010/0323762	A1*	12/2010	Sindhu	G06F 1/1613 455/566
2011/0011936	A1	1/2011	Morandi et al.	
2011/0234545	A1*	9/2011	Tanaka	G06F 3/0416 345/177
2012/0284132	A1	11/2012	Kim et al.	
2013/0130725	A1*	5/2013	Forutanpour	G01C 21/165 455/456.6
2013/0284806	A1*	10/2013	Margalit	G06Q 30/06 235/382
2014/0168121	A1*	6/2014	Chou	G06K 9/00013 345/173
2015/0071502	A1*	3/2015	Breznicky	G06K 9/00885 382/115
2015/0086107	A1	3/2015	Dedeoglu et al.	
2015/0347739	A1*	12/2015	Matsushima	G06F 21/34 726/20
2016/0127900	A1*	5/2016	Archibald	H04W 12/06 726/7
2016/0274398	A1*	9/2016	Hirakata	G06F 3/0416
2017/0124371	A1*	5/2017	Vincent	G06K 9/0002

OTHER PUBLICATIONS

Fischer, Dirk, "Capacitive Touch Sensors. Application Fields, technology overview and implementation example", Fujitsu Microelectronics Europe GmbH. V4, Jan. 12, 2010. Retrieved from Internet: <<URL: http://www.fujitsu.com/downloads/MICRO/fme/articles/fujitsu-whitepaper-capacitive-touch-sensors.pdf>>.

Hasegawa, et al., "Human Body Equivalent Phantom for Analyzing of Surface and Space Propagation in MHz-Band Signal Transmission", Department of Electronics, Kyoto Institute of Technology. Retrievable from Internet: <<http://ieeexplore.ieee.org/document/7481823/>>.

Kalnikaite, et al., "How to Nudge in Situ: Designing Lambent Devices to Deliver Information Salience in Supermarkets", ACM, In proceeding of: UbiComp 2011: Ubiquitous Computing, 13th International Conference, UbiComp 2011, Beijing, China, Sep. 17-21, 2011. Retrieved from Internet: <URL:http://www.researchgate.net/publication/221568350_How_to_nudge_in_Situ_designing_lambent_devices_to_deliver_salient_information_in_supermarkets>.

O'Connor, Todd, "mTouch™ Projected Capacitive Touch Screen Sensing Theory of Operation", Microchip Technology Inc. TB3064. 2010. Retrieved from Internet: <<URL: https://www.microchip.com/stellent/groups/techpub_sg/documents/devicedoc/en550192.pdf>>.

Pop, Cristian, "Introduction to the BodyCom Technology", AN1391, DS01391A, Microchip Technology, Inc., May 2, 2011.

Valtonen, Miika, "Technologies for Smart Environments: Capacitive User Tracking and Proactive Fuzzy Control", Tampere University of Technology. Publication 1044. 2012. Retrieved from Internet: <<http://dspace.cc.tut.fi/dpub/bitstream/handle/123456789/21002/valtonen.pdf?sequence=3&isAllowed=y>>.

Vu, et al., "Distinguishing Users with Capacitive Touch Communication", WINLAB, Rutgers University, In proceedings of: The 18th Annual International Conference on Mobile Computing and Networking ("MobiCom'12"), Aug. 22-26, 2012, Istanbul, Turkey.

* cited by examiner

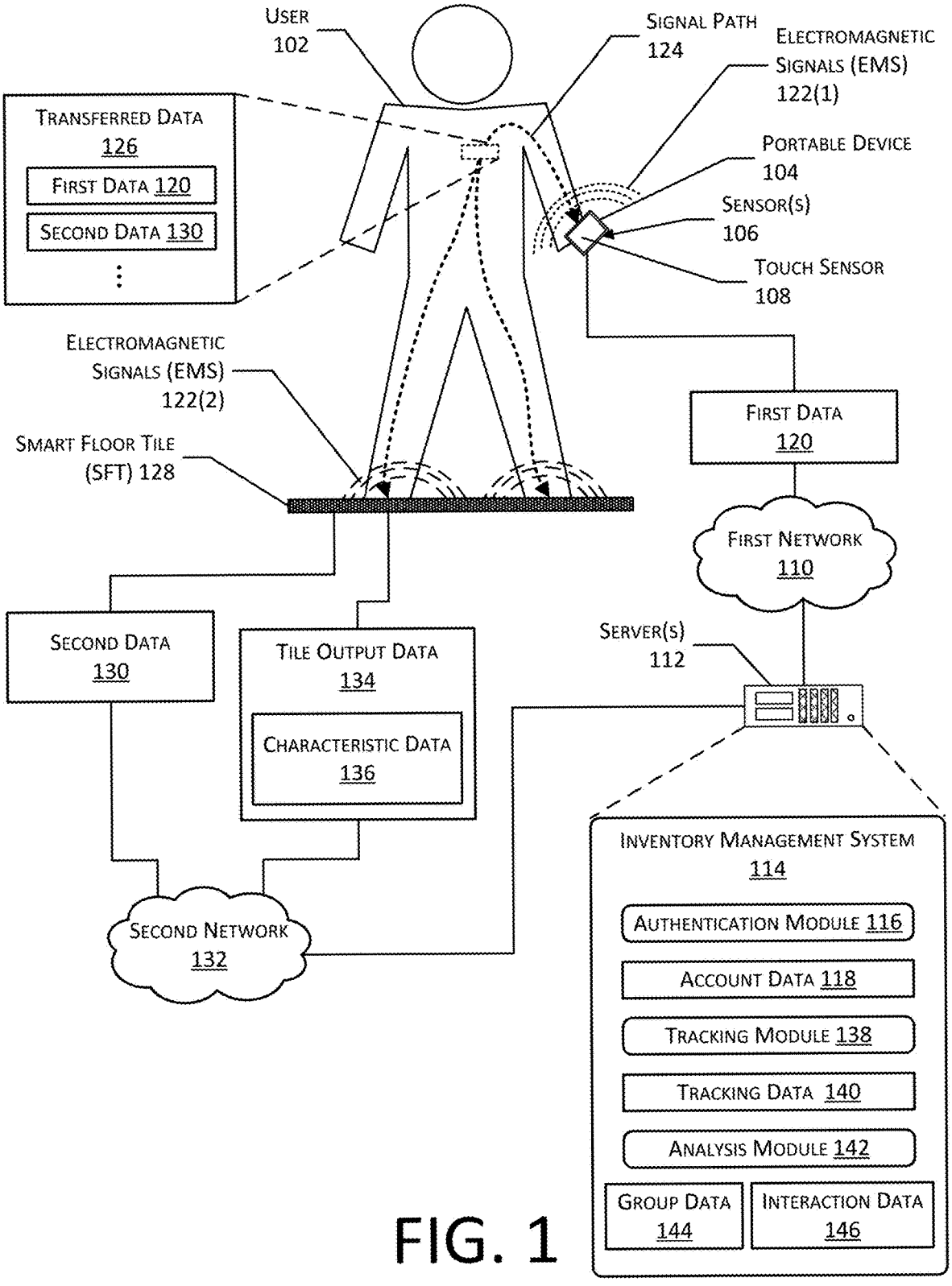

USER
102
SIGNAL PATH
124
ELECTROMAGNETIC
SIGNALS (EMS)
122(1)
TRANSFERRED DATA
126
FIRST DATA 120
SECOND DATA 130
PORTABLE DEVICE
104
SENSOR(S)
106
TOUCH SENSOR
108
ELECTROMAGNETIC
SIGNALS (EMS)
122(2)
SMART FLOOR TILE
(SFT) 128
FIRST DATA
120
FIRST NETWORK
110
SECOND DATA
130
TILE OUTPUT DATA
134
CHARACTERISTIC DATA
136
SERVER(S)
112
INVENTORY MANAGEMENT SYSTEM
114
AUTHENTICATION MODULE 116
ACCOUNT DATA 118
TRACKING MODULE 138
TRACKING DATA 140
ANALYSIS MODULE 142
GROUP DATA
144
INTERACTION DATA
146
SECOND NETWORK
132

FIG. 1

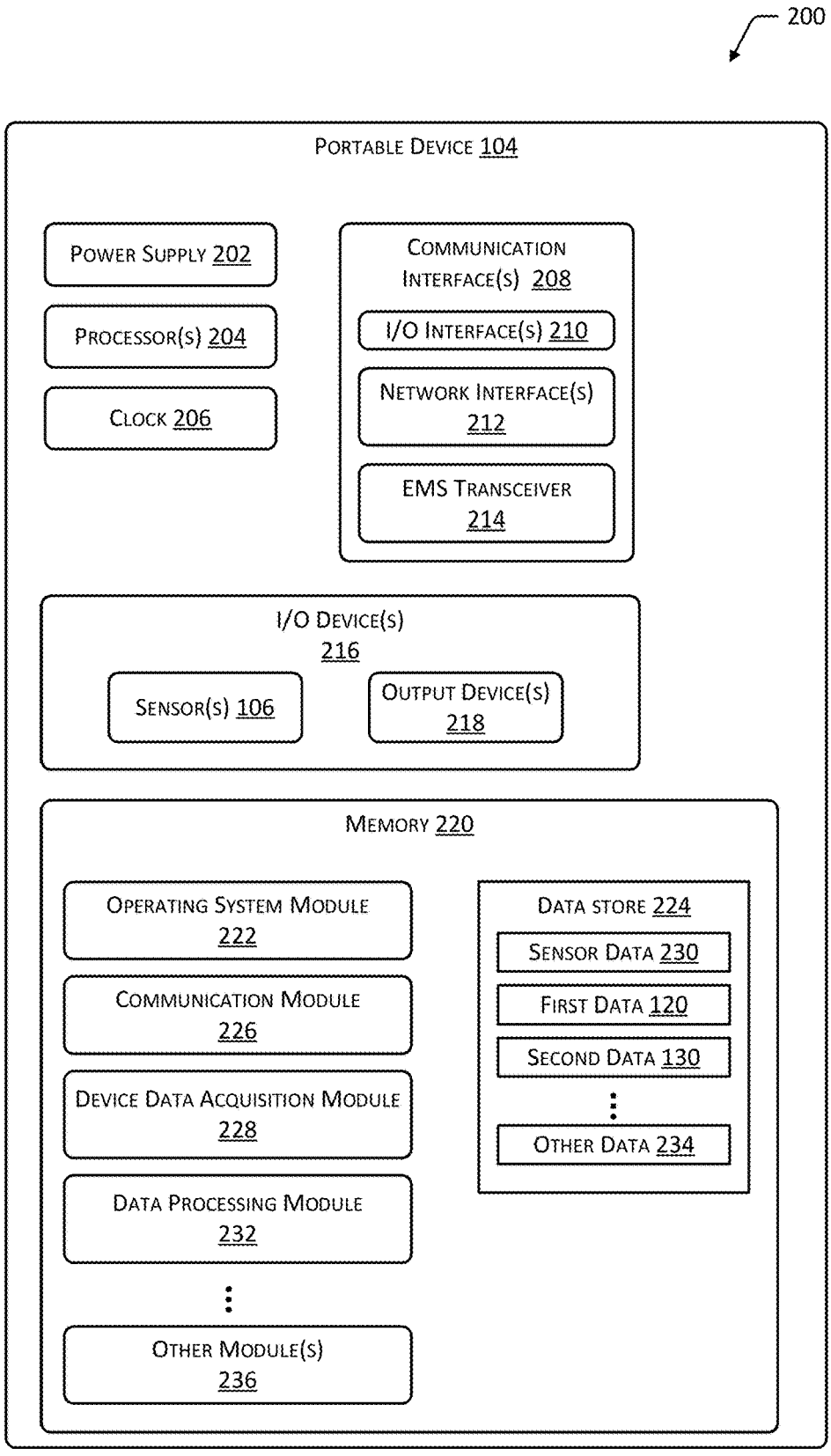

200
PORTABLE DEVICE 104
POWER SUPPLY 202
PROCESSOR(S) 204
CLOCK 206
COMMUNICATION INTERFACE(S) 208
I/O INTERFACE(S) 210
NETWORK INTERFACE(S) 212
EMS TRANSCEIVER 214
I/O DEVICE(S) 216
SENSOR(S) 106
OUTPUT DEVICE(S) 218
MEMORY 220
OPERATING SYSTEM MODULE 222
COMMUNICATION MODULE 226
DEVICE DATA ACQUISITION MODULE 228
DATA PROCESSING MODULE 232
OTHER MODULE(S) 236
DATA STORE 224
SENSOR DATA 230
FIRST DATA 120
SECOND DATA 130
OTHER DATA 234

FIG. 2

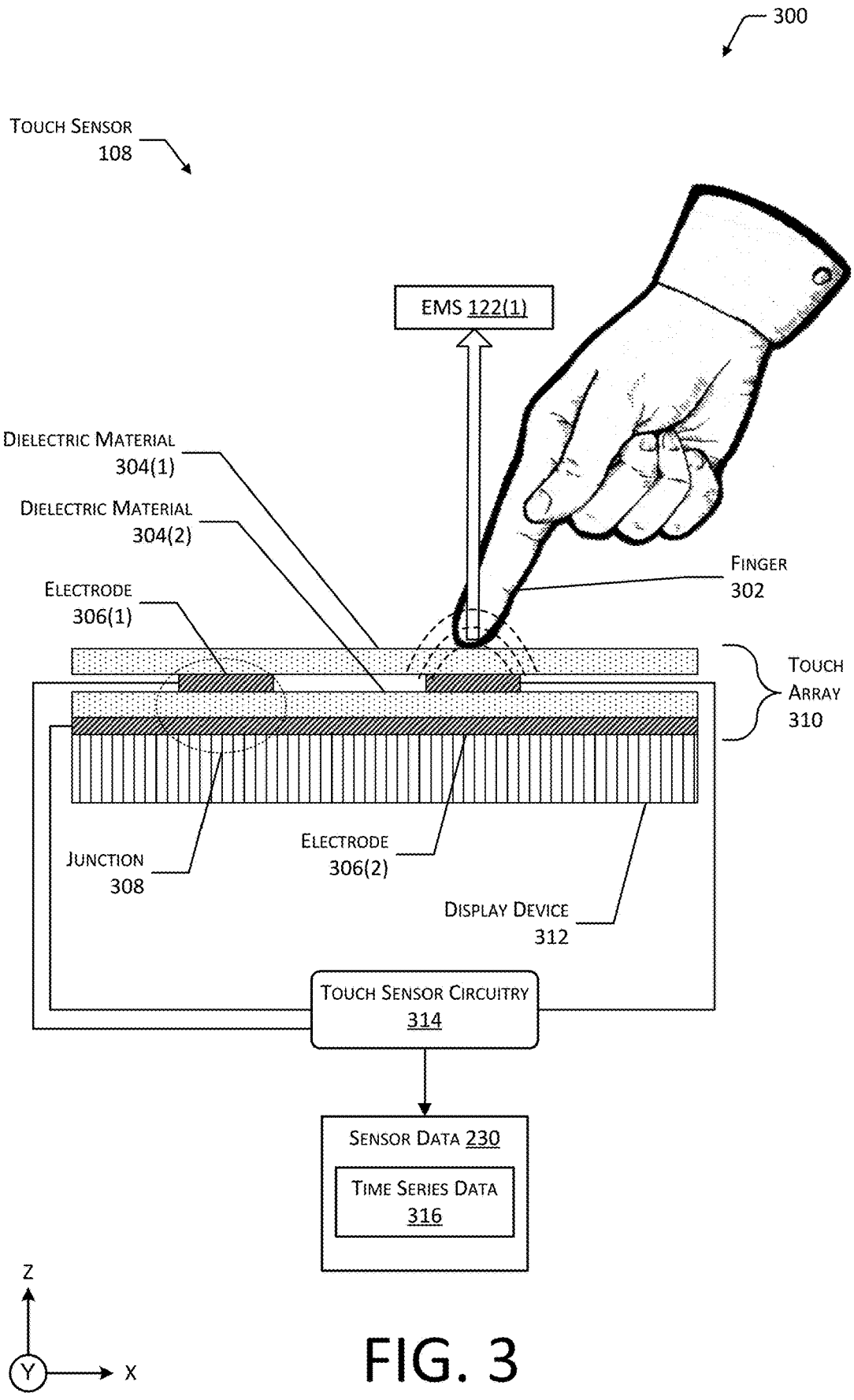

300
TOUCH SENSOR
108
EMS 122(1)
DIELECTRIC MATERIAL
304(1)
DIELECTRIC MATERIAL
304(2)
ELECTRODE
306(1)
FINGER
302
TOUCH
ARRAY
310
JUNCTION
308
ELECTRODE
306(2)
DISPLAY DEVICE
312
TOUCH SENSOR CIRCUITRY
314
SENSOR DATA 230
TIME SERIES DATA
316
Z
Y
X

FIG. 3

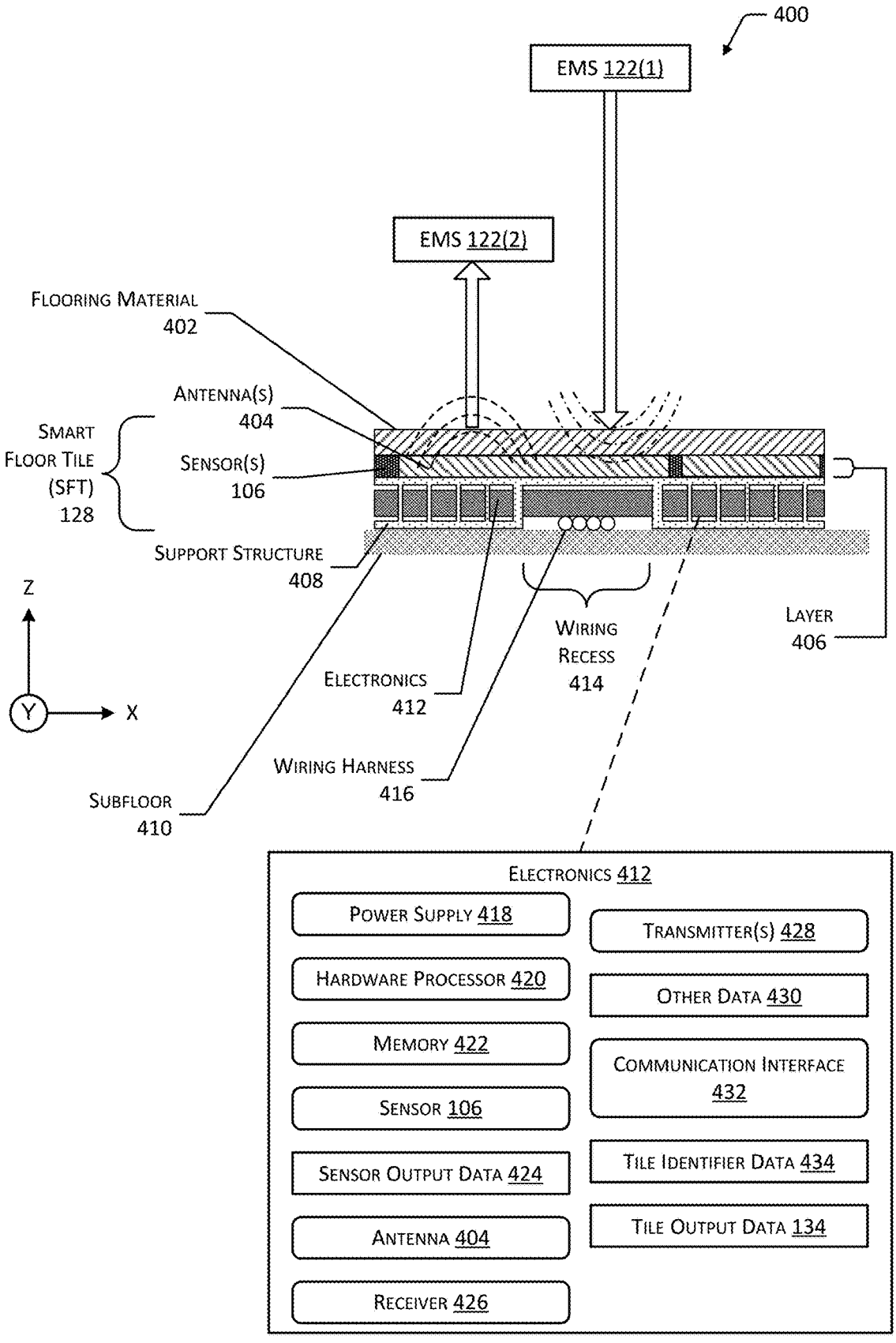

400
EMS 122(1)
EMS 122(2)
FLOORING MATERIAL 402
ANTENNA(S) 404
SMART FLOOR TILE (SFT) 128
SENSOR(S) 106
SUPPORT STRUCTURE 408
Z
Y
X
ELECTRONICS 412
WIRING HARNESS 416
SUBFLOOR 410
WIRING RECESS 414
LAYER 406
ELECTRONICS 412
POWER SUPPLY 418
HARDWARE PROCESSOR 420
MEMORY 422
SENSOR 106
SENSOR OUTPUT DATA 424
ANTENNA 404
RECEIVER 426
TRANSMITTER(S) 428
OTHER DATA 430
COMMUNICATION INTERFACE 432
TILE IDENTIFIER DATA 434
TILE OUTPUT DATA 134

FIG. 4

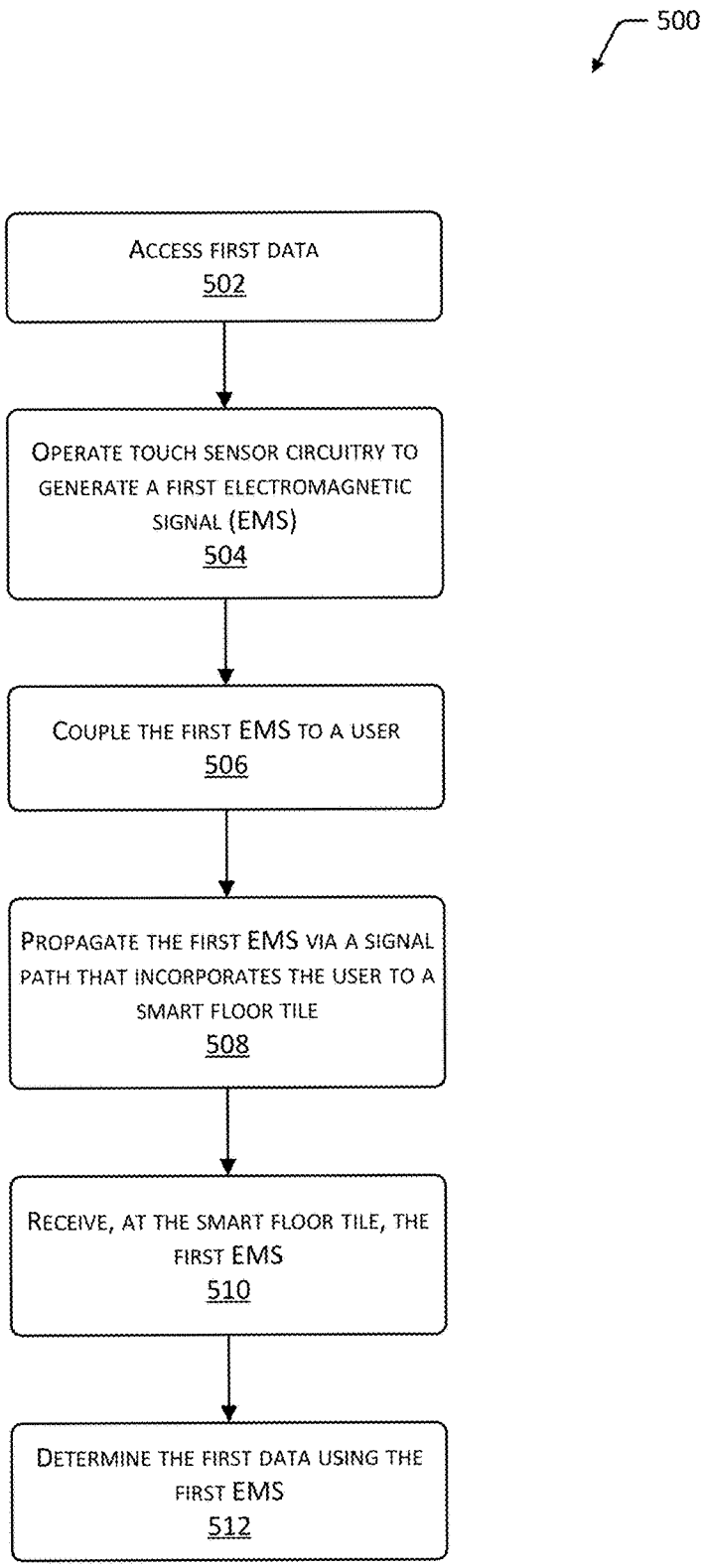

500
ACCESS FIRST DATA
502
OPERATE TOUCH SENSOR CIRCUITRY TO GENERATE A FIRST ELECTROMAGNETIC SIGNAL (EMS)
504
COUPLE THE FIRST EMS TO A USER
506
PROPAGATE THE FIRST EMS VIA A SIGNAL PATH THAT INCORPORATES THE USER TO A SMART FLOOR TILE
508
RECEIVE, AT THE SMART FLOOR TILE, THE FIRST EMS
510
DETERMINE THE FIRST DATA USING THE FIRST EMS
512

FIG. 5

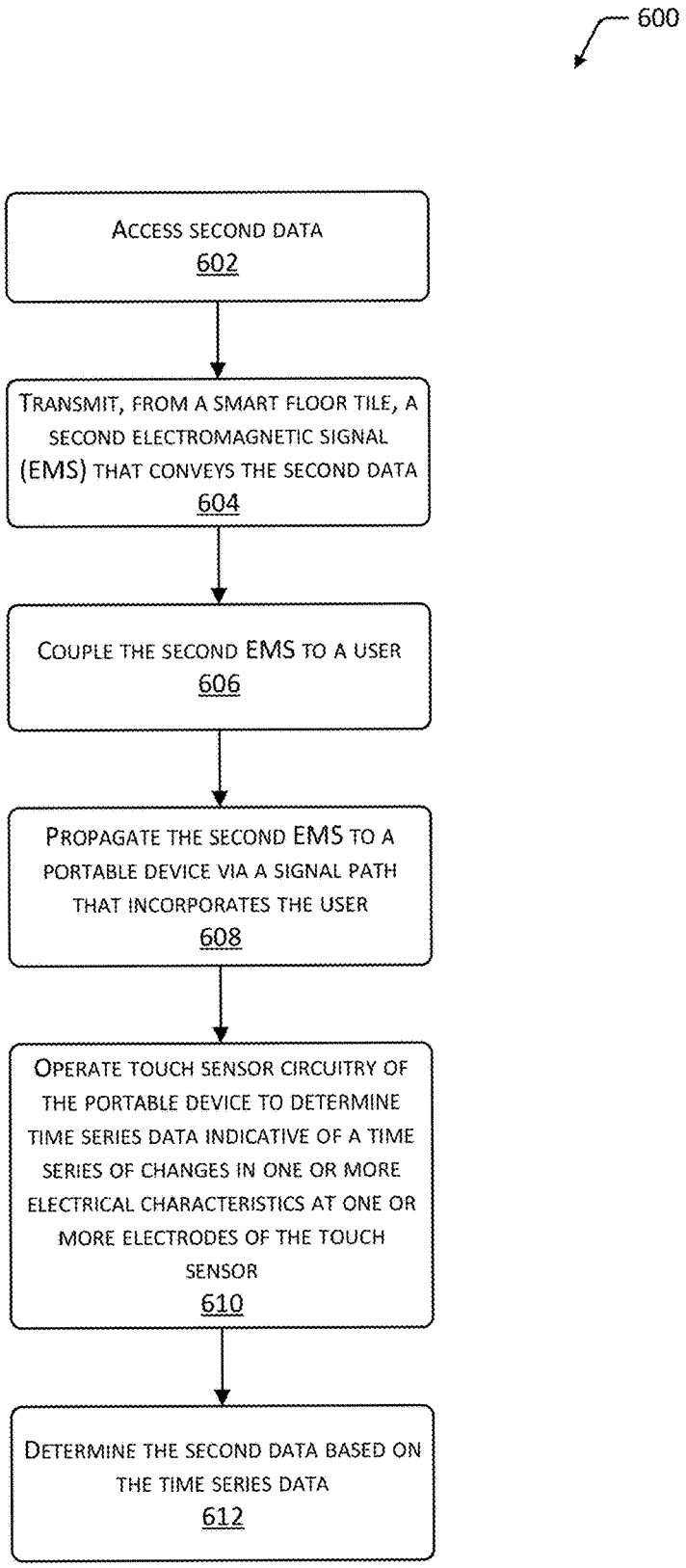

600
ACCESS SECOND DATA
602
TRANSMIT, FROM A SMART FLOOR TILE, A SECOND ELECTROMAGNETIC SIGNAL (EMS) THAT CONVEYS THE SECOND DATA
604
COUPLE THE SECOND EMS TO A USER
606
PROPAGATE THE SECOND EMS TO A PORTABLE DEVICE VIA A SIGNAL PATH THAT INCORPORATES THE USER
608
OPERATE TOUCH SENSOR CIRCUITRY OF THE PORTABLE DEVICE TO DETERMINE TIME SERIES DATA INDICATIVE OF A TIME SERIES OF CHANGES IN ONE OR MORE ELECTRICAL CHARACTERISTICS AT ONE OR MORE ELECTRODES OF THE TOUCH SENSOR
610
DETERMINE THE SECOND DATA BASED ON THE TIME SERIES DATA
612

FIG. 6

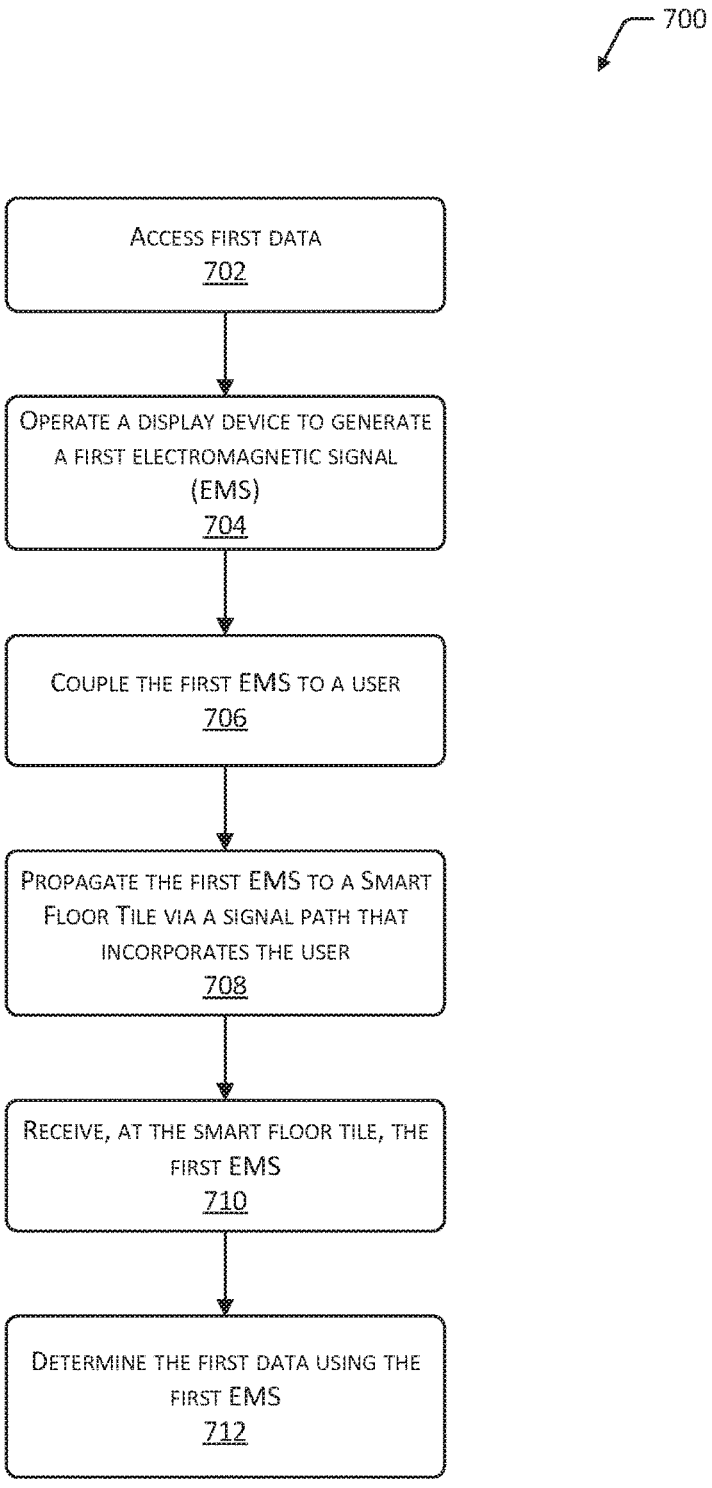

700
ACCESS FIRST DATA
702
OPERATE A DISPLAY DEVICE TO GENERATE A FIRST ELECTROMAGNETIC SIGNAL (EMS)
704
COUPLE THE FIRST EMS TO A USER
706
PROPAGATE THE FIRST EMS TO A SMART FLOOR TILE VIA A SIGNAL PATH THAT INCORPORATES THE USER
708
RECEIVE, AT THE SMART FLOOR TILE, THE FIRST EMS
710
DETERMINE THE FIRST DATA USING THE FIRST EMS
712

FIG. 7

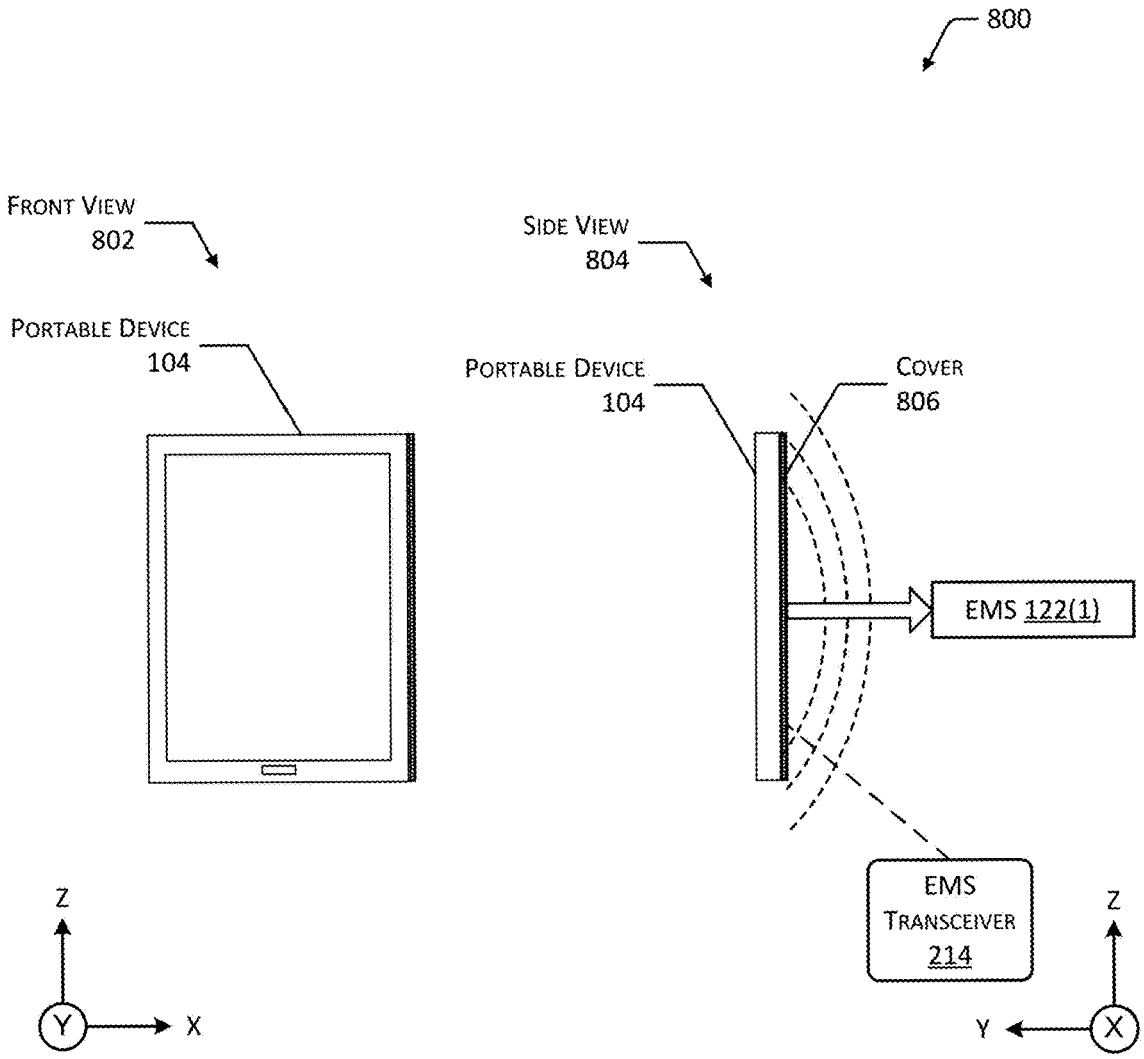

800
FRONT VIEW
802
SIDE VIEW
804
PORTABLE DEVICE
104
PORTABLE DEVICE
104
COVER
806
EMS 122(1)
EMS
TRANSCEIVER
214
Z
Y
X
Z
Y
X

FIG. 8

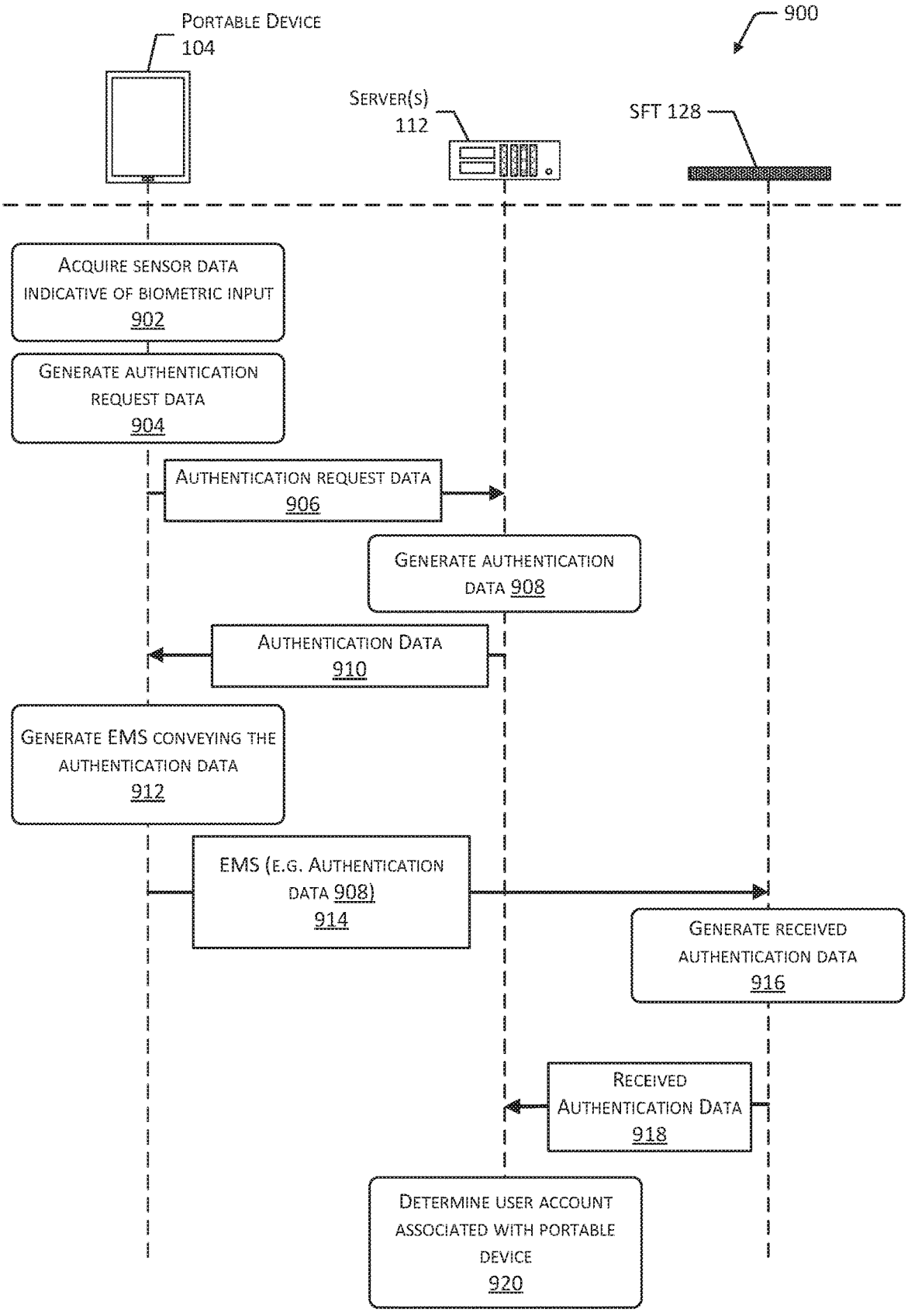

PORTABLE DEVICE
104
900
SERVER(S)
112
SFT 128
ACQUIRE SENSOR DATA INDICATIVE OF BIOMETRIC INPUT
902
GENERATE AUTHENTICATION REQUEST DATA
904
AUTHENTICATION REQUEST DATA
906
GENERATE AUTHENTICATION DATA 908
AUTHENTICATION DATA
910
GENERATE EMS CONVEYING THE AUTHENTICATION DATA
912
EMS (E.G. AUTHENTICATION DATA 908)
914
GENERATE RECEIVED AUTHENTICATION DATA
916
RECEIVED AUTHENTICATION DATA
918
DETERMINE USER ACCOUNT ASSOCIATED WITH PORTABLE DEVICE
920

FIG. 9

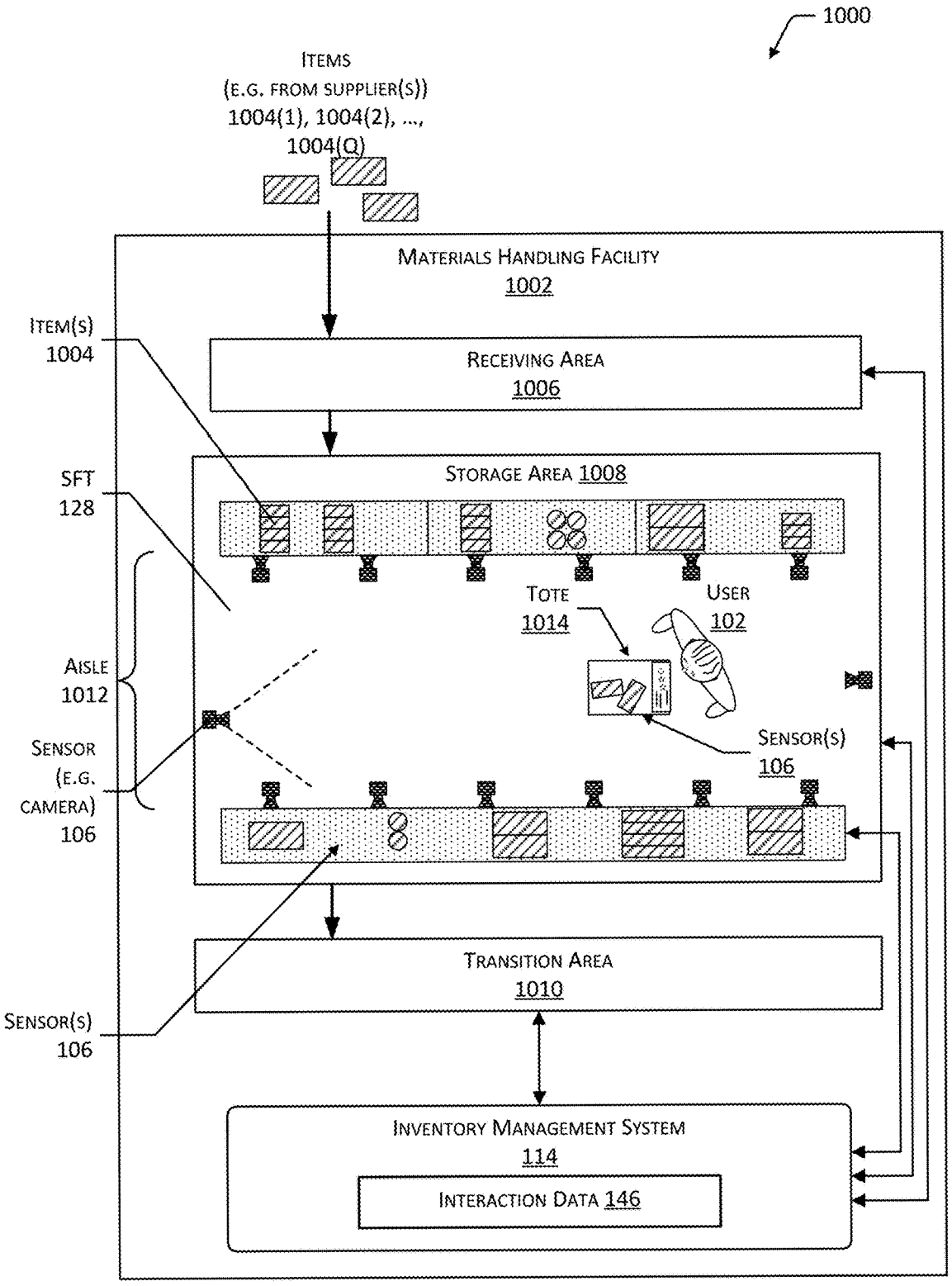

1000
ITEMS
(E.G. FROM SUPPLIER(S))
1004(1), 1004(2), ..., 1004(Q)
MATERIALS HANDLING FACILITY
1002
ITEM(S)
1004
RECEIVING AREA
1006
SFT
128
STORAGE AREA 1008
TOTE
1014
USER
102
AISLE
1012
SENSOR
(E.G. CAMERA)
106
SENSOR(S)
106
TRANSITION AREA
1010
SENSOR(S)
106
INVENTORY MANAGEMENT SYSTEM
114
INTERACTION DATA 146

FIG. 10

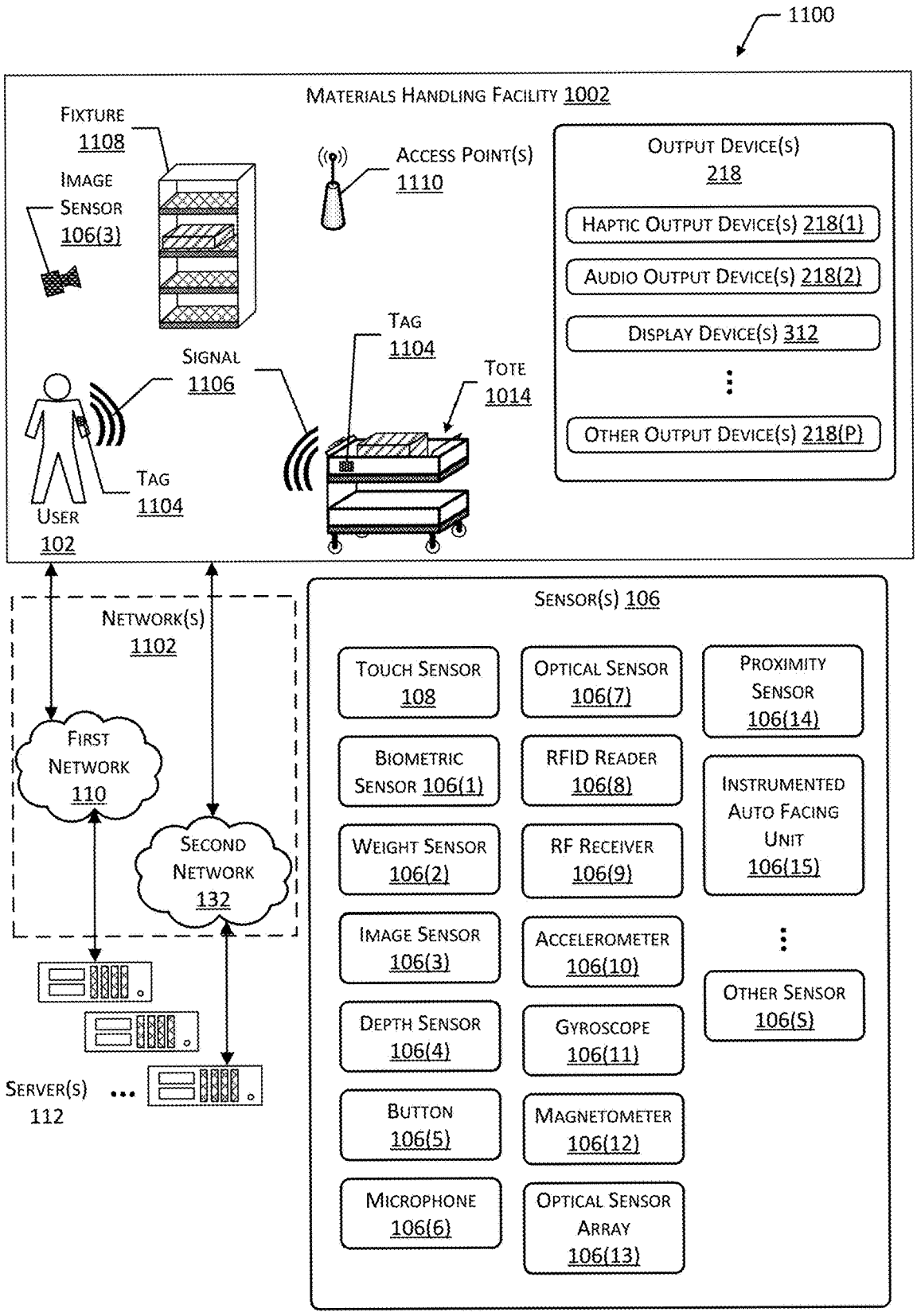

1100
Materials Handling Facility 1002
Fixture 1108
Image Sensor 106(3)
Access Point(s) 1110
Output Device(s) 218
Haptic Output Device(s) 218(1)
Audio Output Device(s) 218(2)
Display Device(s) 312
Other Output Device(s) 218(P)
Tag 1104
Signal 1106
Tote 1014
Tag 1104
User 102
Network(s) 1102
First Network 110
Second Network 132
Server(s) 112
Sensor(s) 106
Touch Sensor 108
Optical Sensor 106(7)
Proximity Sensor 106(14)
Biometric Sensor 106(1)
RFID Reader 106(8)
Instrumented Auto Facing Unit 106(15)
Weight Sensor 106(2)
RF Receiver 106(9)
Image Sensor 106(3)
Accelerometer 106(10)
Other Sensor 106(S)
Depth Sensor 106(4)
Gyroscope 106(11)
Button 106(5)
Magnetometer 106(12)
Microphone 106(6)
Optical Sensor Array 106(13)

FIG. 11

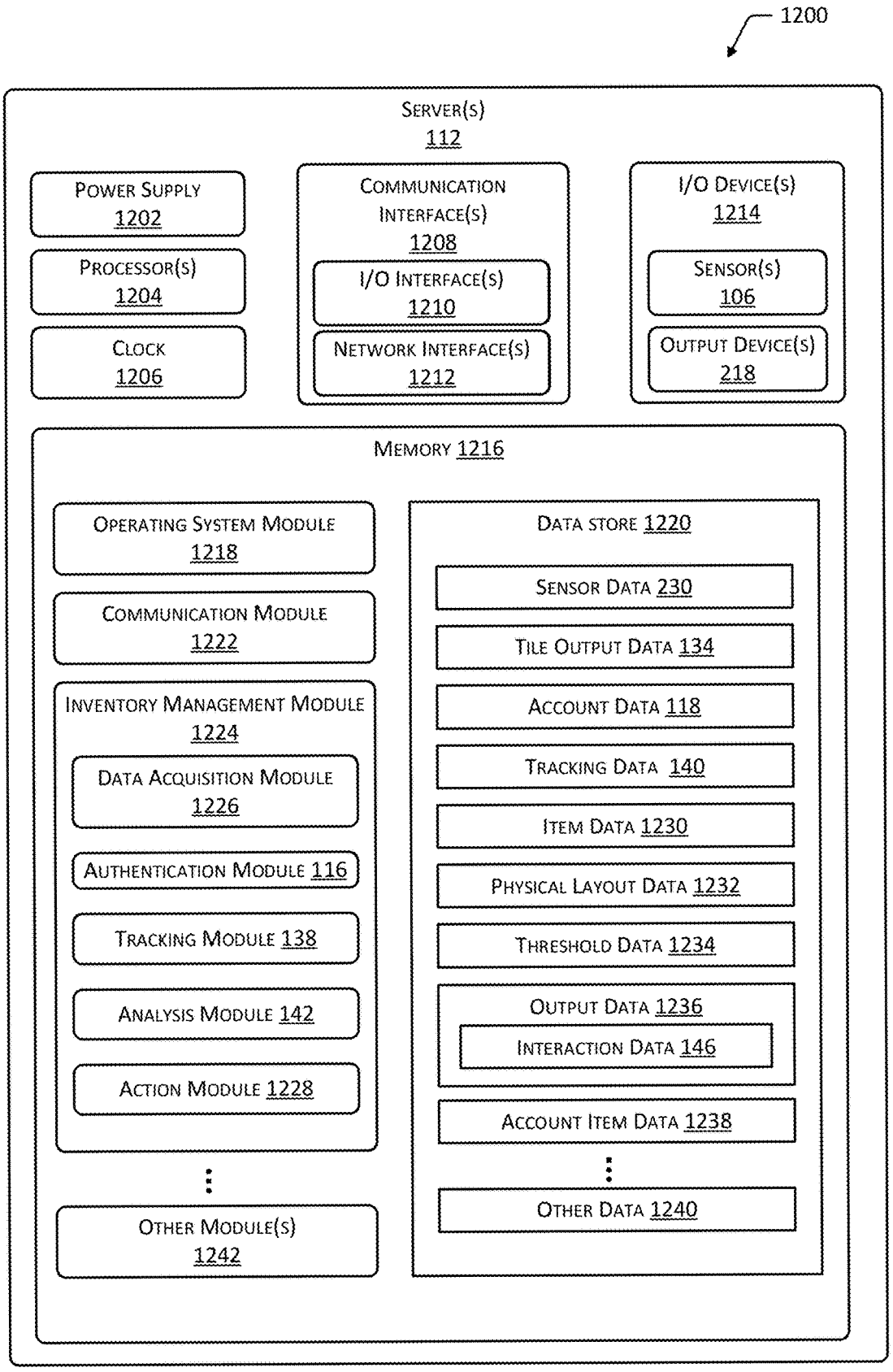

1200
SERVER(S) 112
POWER SUPPLY 1202
PROCESSOR(S) 1204
CLOCK 1206
COMMUNICATION INTERFACE(S) 1208
I/O INTERFACE(S) 1210
NETWORK INTERFACE(S) 1212
I/O DEVICE(S) 1214
SENSOR(S) 106
OUTPUT DEVICE(S) 218
MEMORY 1216
OPERATING SYSTEM MODULE 1218
COMMUNICATION MODULE 1222
INVENTORY MANAGEMENT MODULE 1224
DATA ACQUISITION MODULE 1226
AUTHENTICATION MODULE 116
TRACKING MODULE 138
ANALYSIS MODULE 142
ACTION MODULE 1228
OTHER MODULE(S) 1242
DATA STORE 1220
SENSOR DATA 230
TILE OUTPUT DATA 134
ACCOUNT DATA 118
TRACKING DATA 140
ITEM DATA 1230
PHYSICAL LAYOUT DATA 1232
THRESHOLD DATA 1234
OUTPUT DATA 1236
INTERACTION DATA 146
ACCOUNT ITEM DATA 1238
OTHER DATA 1240

FIG. 12

USER AUTHENTICATION WITH PORTABLE DEVICE AND SMART FLOOR

BACKGROUND

In various facilities, it may be worthwhile to determine an identity of a particular user. For example, an operator of a hospital, warehouse, airplane terminal, and so forth, may want to identify who is on the premises. The user may be identified at a point of entry or exit, or at another point within the facility.

Authenticating the identity of a user who is present at a particular facility or location in the facility may pose various challenges. For example, a user may be required to check in at a front desk, swipe a card at a gate, and so forth, prior to entry. This arrangement uses up floor space for an entry area, requires obtrusive equipment, and is time consuming. For example, if a crowd of users enters the facility in a short span of time, some of those users are delayed entry while waiting for others to be processed. The existing systems thus suffer various impediments to the smooth flow of users while still providing robust authentication.

BRIEF DESCRIPTION OF FIGURES

The detailed description is set forth with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items or features. The figures are not necessarily drawn to scale, and in some figures, the proportions or other aspects may be exaggerated to facilitate comprehension of particular aspects.

FIG. **1** illustrates a system that uses electromagnetic signals between a portable device and a smart floor tile to authenticate a user, according to some implementations.

FIG. **2** illustrates a block diagram of a portable device, according to some implementations.

FIG. **3** illustrates a block diagram of a touch sensor on the portable device, according to some implementations.

FIG. **4** illustrates a block diagram of a smart floor tile, according to some implementations.

FIG. **5** depicts a flow diagram of a process of the portable device using a touch sensor to generate electromagnetic signals to communicate with a smart floor tile, according to some implementations.

FIG. **6** depicts a flow diagram of a process of the portable device using a touch sensor to receive electromagnetic signals transmitted by a smart floor tile, according to some implementations.

FIG. **7** depicts a flow diagram of a process of the portable device using a display device to generate electromagnetic signals to communicate with a smart floor tile, according to some implementations.

FIG. **8** depicts a diagram of a portable device with a cover that includes one or more of a transmitter or a receiver to provide communication with a smart floor tile, according to some implementations.

FIG. **9** depicts a flow diagram of a process of authenticating a user that includes a transfer of data between the portable device and the smart floor tile, according to some implementations.

FIG. **10** is a block diagram illustrating a materials handling facility (facility) using the system, according to some implementations.

FIG. **11** is a block diagram illustrating additional details of the facility, according to some implementations.

FIG. **12** is a block diagram of a server to support operation of the facility, according to some implementations.

While implementations are described herein by way of example, those skilled in the art will recognize that the implementations are not limited to the examples or figures described. It should be understood that the figures and detailed description thereto are not intended to limit implementations to the particular form disclosed but, on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope as defined by the appended claims. The headings used herein are for organizational purposes only and are not meant to be used to limit the scope of the description or the claims. As used throughout this application, the word "may" is used in a permissive sense (i.e., meaning having the potential to), rather than the mandatory sense (i.e., meaning must). Similarly, the words "include", "including", and "includes" mean "including, but not limited to".

DETAILED DESCRIPTION

Described in this disclosure are systems and techniques for authenticating a user that is present at a facility. The facility may include a residence, workplace, public facility, and so forth. For example, the facility may comprise a materials handling facility that includes, or has access to, an inventory management system. The inventory management system may be configured to maintain information about items, users, condition of the facility, and so forth. Continuing the example, the inventory management system may maintain data indicative of a number of items at a particular fixture, what items a particular user is ordered to pick, how many items have been picked or placed at the fixture, requests for assistance, environmental status of the facility, and so forth.

In some situations, it may be worthwhile to authenticate the identity of a particular user as being present at the facility at a particular time. For example, an operator of a warehouse may want to know who has entered the facility and when.

The floor of the facility may comprise a plurality of smart floor tiles (SFTs). The SFTs may include transmitters that generate electromagnetic signals (EMS), receivers to detect EMS, or both such as in a transceiver. In some implementations, these signals may be low frequency, in that the carrier has a frequency of less than or equal to 30 MHz. The SFTs may also include sensors such as touch or pressure sensors that provide object data indicative of an object such as a foot or wheel that is in contact with the smart floor tile.

The user is equipped with a portable device, such as a smart phone, wearable computing device, and so forth. The portable device is able to send, receive, or both send and receive EMS that may be received from or transmitted to the smart floor tiles. The portable device may generate the EMS using hardware such as a touch sensor, display device, and so forth. For example, touch sensor control circuitry may be directed to scan particular junctions in a touch sensor array at a greater frequency, increase an amplitude of the scan signal, and so forth. In another example, the display device may be directed to present particular images to produce the EMS. In other implementations, the portable device may include a dedicated EMS transmitter, EMS receiver, or both.

An object may electromagnetically couple to a proximate antenna or electrode. Once electromagnetically coupled, the object may act as a propagation path for the EMS. For example, when a user is standing on an SFT, their foot

electromagnetically couples to an antenna in the SFT. Continuing the example, when the user is touching a touch screen, their finger electromagnetically couples to one or more of the electrodes in the junction of the touch sensor. As a result, the body of the user provides a signal path between the portable device and the SFT. This signal path may be used to communicate data which may then be used to authenticate the user.

Authentication of the user may utilize the communication between the portable device and the SFT by way of the EMS and the signal path provided by the body of the user to authenticate the user. In one implementation, the portable device may include a fingerprint scanner which is used to obtain biometric data such as fingerprint data. The fingerprint data may be included in a request for authentication data. The portable device may use a network connection and send this authentication request data to a server. The server may then process the authentication request data and determine that the information about the fingerprint indeed corresponds to a particular user account, and return authentication data. For example, the authentication data may include a token that comprises a value that expires after a predetermined time or a particular event. The portable device receives this authentication data and may then generate an EMS that conveys or otherwise represents the authentication data, such as the value of the token. The authentication data is transmitted from the portable device to the SFT by way of the signal path provided by contact with both. For example, while the user's finger is in contact with the touch sensor, the authentication data may be transmitted. The SFT receives the authentication data and may then pass that authentication data back to the server. The server may then compare the authentication data that it provided to the portable device with that obtained from the SFT. If the two match, the user is deemed to be authenticated as present at the SFT and is then associated with the user account that corresponds to the authentication data. Other implementations may also be realized. For example, the portable device may send to the SFT information indicative of the biometric data, such as a hash of the fingerprint data, which is then sent along to the server for comparison.

Operation of the facility may be facilitated by using one or more sensors to acquire information about interactions in the facility. By authenticating the user, particular interactions may be associated with particular users. The inventory management system may process the sensor data from the one or more sensors to determine tracking data, interaction data, and so forth. The tracking data provides information about the location of a user within the facility, their path through the facility, and so forth. The interaction data is indicative of an action such as picking or placing an item at a particular location on the fixture, touching an item at a particular location on the fixture, presence of the user at the fixture without touching the item, and so forth. For example, the inventory management system may use the sensor data to generate tracking data and interaction data that determines a type of item a user picked from a particular fixture.

A fixture may include one or more item stowage areas such as shelves, hangers, and so forth, that hold or otherwise support a type of item. The fixture may be arranged into sections, such as lanes on a shelf. For example, a shelf may have three lanes, with each lane holding a different type of item. Items may be added to (placed) or removed (picked) from the fixture, moved from one fixture to another, and so forth. By using sensors or other devices at the fixtures, the particular user account of the user may be billed for particular interactions, such as a pick of a particular item.

By using the techniques described herein, operation of the facility may be improved. Details about the presence and movement of particular users in the facility, the interactions between the particular users and items in the facility, and so forth, may be quickly and accurately determined. For example, as items are picked, placed, and so forth, information such as inventory levels based on changes in the count of items at the fixtures may be readily and more accurately determined. As a result, the inventory management system may be able to quickly track what item a user has interacted with, maintain up-to-date inventory information, and so forth. Tracking of users may be facilitated, allowing for enhanced services to the users of the facility, such as making the facility respond to the presence of a user. For example, as an authorized user approaches a fixture holding items that is locked, the fixture may unlock to provide access.

The use of the communication between the portable device and the SFT by way of the EMS allows for highly localized communications and assurance that a particular user is in the facility. Given that the SFT is known to be within the facility, and even at a particular location within the facility, communication using the SFT provides a high assurance as to the physical presence of the user and their portable device. By using the portable devices of the users to provide the input or other information involved in authenticating the user, bottlenecks such as a check-in desk or limited number of physical entry gates with card readers are further avoided.

Illustrative System

FIG. **1** illustrates a system **100** using electromagnetic signals (EMS) between a portable device and a smart floor tile (SFT) to authenticate a user, according to some implementations.

A user **102** has a portable device **104**. The portable device **104** may include a smart phone, wearable device, tablet computer, and so forth. The portable device **104** may include one or more sensors **106**, such as a touch sensor **108**. The touch sensor **108** may comprise a capacitive touch sensor, a resistive touch sensor, and so forth. The portable device **104** may include a communication interface that allows the portable device **104** to establish communication with the first network **110**. For example, the communication interface may comprise a Wi-Fi or Bluetooth interface that allows connection to an access point or another computing device. The first network **110** may comprise a local area network, wide area network, and so forth. The portable device **104** may be able to establish communication with a server **112** using the first network **110**. The server **112** may include an inventory management system **114**.

The inventory management system **114** may include an authentication module **116**. The authentication module **116** may be configured to determine a particular user account, as stored in account data **118**, that is associated with a physical presence of the user **102** at the facility. For example, the authentication module **116** may compare authentication data that is obtained from different devices to determine if a user **102** associated with a particular user account is present at a particular location. Operation of the authentication module **116** is discussed in more detail below.

The portable device **104** may generate first data **120** or receive the first data **120** from another device, such as the server **112**. For example, the first data **120** may comprise authentication data generated by the portable device **104**, by the authentication module **116**, and so forth.

The portable device **104** may transmit or receive electromagnetic signals (EMS) **122** propagated along a signal path

124. These EMS 122 may be propagated along a signal path 124 that may include the body of a user 102 or other objects. For example, the signal path 124 of the EMS 122 may include the point of contact of the user 102 with the portable device 104, the user's 102 body, and another device such as a smart floor tile (SFT) 128. In some implementations, the EMS 122 may have a carrier frequency of between 20 kilohertz and 15 megahertz. The EMS 122 may be used to communicate transferred data 126, such as the first data 120.

The facility includes a floor that may comprise one or more SFTs 128. In some implementations, the SFTs 128 may be arranged into a group designated as a cluster. The floor may include a plurality of clusters. The SFT 128 may include one or more of a transmitter to transmit the EMS 122, a receiver to receive the EMS 122, or both a transmitter and a receiver.

The SFT 128 may generate second data 130 or receive the second data 130 from another device, such as the portable device 104, the server 112, and so forth. For example, the second data 130 may comprise authentication data generated by the authentication module 116. The transferred data 126 may also include the second data 130.

The SFT 128 may include a communication interface that allows the SFT 128 to establish communication with a second network 132. For example, the communication interface may comprise a Controller Area Network (CAN) interface that connects to the second network 132. The server 112 may also be in communication with the second network 132. For example, the SFT 128 may be able to send or receive second data 130 to and from the server 112.

One or more processors of the SFT 128 may generate tile output data 134. The tile output data 134 may include characteristic data 136. The characteristic data 136 may provide information about the EMS 122 received by the SFT 128. For example, the characteristic data 136 may be indicative of a frequency of a received signal, signal strength of the received signal, phase of the received signal, and so forth. In some implementations, the characteristic data 136 may be used to determine the location of the user 102 within the facility.

During operation of the system, the transferred data 126 may be used to authenticate the user 102. In one implementation, the sensors 106 may include biometric sensors such as fingerprint readers, cameras, and so forth. The portable device 104 may execute an application that communicates with the server 112. The portable device 104 may send information based on the sensor data obtained from the one or more sensors 106 to the server 112. For example, fingerprint data representative of the fingerprint of the user 102 is obtained from a fingerprint reader may be hashed, encrypted, and so forth. The fingerprint data may be sent to the server 112 for processing by the authentication module 116. The authentication module 116 may determine that the fingerprint data corresponds to a particular user account specified by the account data 118 and generates authentication data. For example, the authentication data may comprise a token or value. The authentication data is then returned to the portable device 104. In this implementation, the portable device 104 may transmit the first data 120 that includes the authentication data to the SFT 128 using the EMS 122. For example, the EMS 122(1) as transmitted by the portable device 104 conveys the first data 120.

Continuing this implementation, the SFT 128 receives the EMS 122(1), decodes it, and generates second data 130 that is indicative of the authentication data. The SFT 128 may then transmit the second data 130 to the inventory management system 114. The authentication module 116 may then compare the first data 120 with the second data 130 to determine if the authentication data as provided to the portable device 104 matches that which was received by the SFT 128. When the two match, the user 102 associated with the user account may be deemed to be present at the facility. In some implementations, timestamps associated with the data may be compared to determine that the first data 120 and the second data 130 are within a threshold amount of time of one another. For example, the authentication module 116 may discard second data 130 that does not have a timestamp value that is within three seconds of a timestamp value associated with sending the first data 120 to the portable device 104.

In other implementations, other techniques may be used. For example, the SFT 128 may transmit a second EMS 122(2) that conveys the authentication data, while the portable device 104 is used to receive this second EMS 122(2). By using the signal path 124 of the EMS 122 between the portable device 104 and the SFT 128, information may be transmitted between the two with a high degree of assurance that the portable device 104 is located at the SFT 128. By utilizing biometric sensors, there may be a high degree of assurance that the user 102 is present with the portable device 104 which is located at the SFT 128.

The portable device 104, the SFT 128, or both may transmit continuously or periodically. For example, the SFTs 128 may continuously transmit the EMS 122(2) that are indicative of the particular tile or portion thereof.

With the user 102 authenticated, and a particular user account known and associated with that user 102, the inventory management system 114 may be used to provide other information. The inventory management system 114 may include a tracking module 138. The tracking module 138 may use the tile output data 134 or data from other fixtures to generate tracking data 140. The fixture may include shelves, hangers, cubbyholes, and so forth, that are configured to store one or more items. The tracking data 140 may include one or more of information indicative of a user path within the facility, current location, location at a particular time, and so forth. In some implementations, the tracking module 138 may be executed as a tracking system, such as provided by one or more computing devices. In some implementations, the tracking module 138 may use the characteristic data 136 to further distinguish between users 102 or other objects. For example, the user 102, a tote, or other object may include a transmitter that emits a discrete EMS 122 or a receiver that receives the EMS 122 and provides characteristic data 136. In some implementations, the distribution of received EMS 122 signal amplitude with respect to feet (such as greater signal strength at the toe than at the heel) may be used to determine an approximate shape of the foot that is indicative of a particular user 102 or other object to be tracked. This data may be used instead of, or in conjunction with, the characteristic data 136 to generate the tracking data 140.

An analysis module 142 may use the tracking data 140 to generate group data 144. The group data 144 may comprise information that associates a plurality of users 102 as belonging to a common group or having a common affiliation. For example, members of a family within the facility may be deemed to be a group, members of the same picking crew may be members of a group, and so forth. In some implementations, the tile output data 134 may be processed to determine the group data 144. For example, several users 102 may be holding hands or otherwise in physical contact with one another. As a result of this contact, the EMS 122(2) from a first SFT 128(1) may be transferred through those

users **102** to the receivers of the SFTs **128** beneath each of the other members of the group. By determining the presence of a plurality of users **102**, such as by multiple footprints detected by the sensors within the SFTs **128** that share a common EMS **122** that conveys the same characteristic data **136**, group data **144** may be determined.

The analysis module **142** may also generate interaction data **146**. The interaction data **146** is indicative of an action such as picking or placing an item at a particular fixture, approaching but not touching an item stowed at the fixture, presence of the user **102** at the fixture, and so forth. For example, the analysis module **142** may use tracking data **140** to determine that a particular user **102** was in front of a particular fixture at a time when that fixture experienced a change in quantity of items stowed therein. Based on this correspondence, a particular user **102** may be associated with that change in quantity, and interaction data **146** indicative of this may be generated.

The analysis module **142** may also use data obtained from one or more sensors **106** or other devices located at or near a fixture to generate the interaction data **146**. In one implementation, the fixture may include one or more receivers that are able to receive the EMS **122**. As the user **102** comes into contact with the item stowed at the fixture, their body and the item itself provide a signal path **124** for the EMS **122** to be transferred to an antenna located at the fixture. As a result, use of the SFT **128** and the EMS **122** provides the additional benefit of unambiguously identifying an item that the particular user **102** interacted with. The analysis module **142** is configured to generate the interaction data **146** based on inputs including, but not limited to, the tile output data **134**, the fixture, and so forth.

In some implementations, the techniques described here may be used to provide for communication between devices. For example, a first portable device **104(1)** may exchange transferred data **126** with a second portable device **104(2)** using the EMS **122**. In another example, the portable device **104** may exchange transferred data **126** with an electronic door lock.

By using the devices and the techniques described in this disclosure, the user **102** may be authenticated and affirmatively identified with respect to a particular user account or other identifying information. With the identity of the user **102** assured, the inventory management system **114** or other systems are able to correctly associate a particular interaction with that user **102**.

FIG. **2** illustrates a block diagram **200** of the portable device **104**, according to some implementations. The portable device **104** may comprise one or more of a smart phone, wearable computer, fitness tracker, tablet computer, and so forth.

The portable device **104** may include one or more power supplies **202**. The one or more power supplies **202** may comprise batteries, capacitors, fuel cells, photovoltaic cells, wireless power receivers, conductive couplings suitable for attachment to an external power source such as provided by an electric utility, and so forth. The portable device **104** may include one or more hardware processors **204** (processors) configured to execute one or more stored instructions. The processors **204** may comprise one or more cores. One or more clocks **206** may provide information indicative of date, time, ticks, and so forth. For example, the processor **204** may use data from the clock **206** to associate a particular interaction with a particular point in time.

The portable device **104** may include one or more communication interfaces **208** such as I/O interfaces **210**, network interfaces **212**, and so forth. In some implementations, the communication interfaces **208** may include an EMS transmitter, an EMS receiver, or an EMS transceiver **214**. The communication interfaces **208** enable the portable device **104**, or components thereof, to communicate with other devices or components.

The communication interfaces **208** may include one or more of the I/O interfaces **210**. The I/O interfaces **210** may comprise I2C, SPI, USB, RS-232, and so forth. The I/O interface(s) **210** may couple to one or more I/O devices **216**. The I/O devices **216** may include input devices such as one or more sensors **106**, a touch sensor **108**, keyboard, mouse, scanner, and so forth. The I/O devices **216** may also include output devices **218** such as one or more of a display device, audio speakers, and so forth. In some embodiments, the I/O devices **216** may be physically incorporated with the portable device **104** or may be externally placed.

The network interfaces **212** may be configured to provide communications between the portable device **104**, routers, access points, and so forth. The network interfaces **212** may include devices configured to couple to personal area networks (PANs), local area networks (LANs), wireless local area networks (WLANS), wide area networks (WANs), wireless cellular data network (WCDN), and so forth. For example, the WCDN interface may allow connection to a 3G, 4G, LTE, or other cellular data networks.

The portable device **104** may also include one or more busses or other internal communications hardware or software that allow for the transfer of data between the various modules and components of the portable device **104**.

As shown in FIG. **2**, the portable device **104** includes one or more memories **220**. The memory **220** may comprise one or more non-transitory computer-readable storage media (CRSM). The CRSM may be any one or more of an electronic storage medium, a magnetic storage medium, an optical storage medium, a quantum storage medium, a mechanical computer storage medium, and so forth. The memory **220** provides storage of computer-readable instructions, data structures, program modules, and other data for the operation of the portable device **104**. A few example functional modules are shown stored in the memory **220**, although the same functionality may alternatively be implemented in hardware, firmware, or as a SoC.

The memory **220** may include at least one operating system (OS) module **222**. The OS module **222** is configured to manage hardware resource devices such as the I/O interfaces **210**, the I/O devices **216**, the communication interfaces **208**, and provide various services to applications or modules executing on the processors **204**. The OS module **222** may implement a variant of the FreeBSD operating system as promulgated by the FreeBSD Project; other UNIX or UNIX-like variants; a variation of the Linux operating system as promulgated by Linus Torvalds; the Windows operating system from Microsoft Corporation of Redmond, Wash., USA; and so forth.

Also stored in the memory **220** may be a data store **224** and one or more of the following modules. These modules may be executed as foreground applications, background tasks, daemons, and so forth. The data store **224** may use a flat file, database, linked list, tree, executable code, script, or other data structure to store information. In some implementations, the data store **224** or a portion of the data store **224** may be distributed across one or more other devices including the servers **112**, network attached storage devices, and so forth.

A communication module **226** may be configured to establish communications with the inventory management

system **114**, the SFTs **128**, or devices associated therewith. The communications may be authenticated, encrypted, and so forth.

The memory **220** may store a device data acquisition module **228**. The device data acquisition module **228** may be configured to acquire sensor data **230** from sensors onboard or in communication with the portable device **104**. For example, the device data acquisition module **228** may be used to obtain sensor data **230** from the one or more sensors **106** such as a fingerprint reader, iris scanner, and so forth, that generate biometric data about the user **102**. In some implementations, the biometric data may be indicative of a behavioral or physical characteristic of the user **102**. For example, the way the user **102** types, manipulates a mouse, manipulates the touch sensor **108**, moves the portable device **104** around in space, and so forth, may be used to generate metric data.

The data store **224** may be used to store one or more of the sensor data **230**, the first data **120**, the second data **130**, and so forth.

The memory **220** includes a data processing module **232** that may use as input one or more of the sensor data **230**, the first data **120**, the second data **130**, or other data **234**. For example, the data processing module **232** may be configured to establish communication with the inventory management system **114** using the communication interfaces **208**.

The data processing module **232**, the communication module **226**, or other modules **236** may be configured to use I/O devices **216** to communicate with the SFT **128**. In one implementation, the data processing module **232** may generate instructions or otherwise operate the touch sensor **108** to generate the EMS **122**(**1**). For example, the data processing module **232** may direct the touch sensor **108** to apply voltages at particular times to particular electrodes within the touch sensor **108**. The EMS **122** may then be radiated using the particular electrodes. Other techniques may be used to generate EMS **122** using the touch sensor **108**. For example, the clock frequency of the touch sensor **108** may be varied to generate the EMS **122**. In another example, a local oscillator frequency may be used to generate the EMS **122** during operation of the touch sensor **108**. For example, an oscillator may be used to generate an alternating current at radio frequencies, such as between 10 kHz and 15 MHz. This alternating current may be used to provide a time changing voltage to the junctions **308**. In some implementations, the local oscillator frequency may be controllable, such that the frequency, phase, amplitude, and so forth, of the output from the local oscillator may be changed to convey data.

In another implementation, the data processing module **232** may process data obtained by the touch sensor **108** to receive data transmitted via an EMS **122**. For example, the EMS **122** as propagated along the signal path **124** from the SFT **128** to the portable device **104** may be detected by the touch sensor **108** as touch events. Duration of touch, timestamp of the touch, relative position with respect to the touch sensor **108**, number of simultaneous touches, or other data about the touch events may be expressed as touch event data. For example, the sensor data **230** may include touch event data. The data processing module **232** may process the touch event data and determine that 47 touches occurred during 100 milliseconds. These touch events may be deemed to have occurred too quickly to be an actual human interaction, and thus may be processed to decode information conveyed by the touch events.

The data processing module **232** may also provide other functions. For example, the data processing module **232** may authenticate the user **102** using sensor data **230** obtained by the one or more sensors **106** of the portable device **104**. For example, the data processing module **232** may obtain fingerprint data from a fingerprint reader. The fingerprint data may be compared with a locally stored value or may be sent using the communication interface **208** to the server **112**.

Other modules **236** may also be present in the memory **220**. For example, the other modules **236** may include a cryptographic module used to encrypt or decrypt data transmitted using the EMS **122**.

FIG. **3** illustrates a block diagram **300** of the touch sensor **108** that may be part of the portable device **104**, according to some implementations. A finger **302** of the user **102** is in contact with (or proximate to) a portion of the touch sensor **108**. The touch sensor **108** may comprise one or more layers of dielectric material **304** that separate one or more electrodes **306**. The dielectric material **304** acts as an electrical insulator. The dielectric material **304** may be a solid such as a plastic, a gas such as air, a vacuum, and so forth. As depicted in this figure, the dielectric material **304**(**1**) may comprise glass that provides an uppermost layer of the touch sensor **108**. Under the dielectric material **304**(**1**), a first set of one or more electrodes **306**(**1**) are arranged. For example, these electrodes **306**(**1**) may be arranged in columns. Beneath the one or more electrodes **306**(**1**) is dielectric material **304**(**2**). Beneath the dielectric material **304**(**2**), a second set of one or more electrodes **306**(**2**) are arranged. Continuing the example, this second set of electrodes **306**(**2**) may be arranged in rows. Together, the first set of electrodes **306**(**1**) and the second set of electrodes **306**(**2**) produce an array of junctions **308**, with each junction **308** comprising the intersection between a particular row and column of electrodes **306**. A touch array **310** may comprise the dielectric material **304** and the electrodes **306**. In other implementations, the touch array **310** may comprise discrete electrodes **306** or pairs of electrodes **306** forming junctions **308** that act as touch sensitive areas.

The touch array **310** may be at least partially transparent to optical wavelengths of light. For example, the dielectric material **304** may comprise glass or plastic. Likewise, the electrodes **306** may be transparent. For example, the electrodes **306** may comprise indium tin oxide (ITO). In another example, the electrodes **306** may have a small feature size, to minimize impact on the transmission of an image through the touch array **310**.

In some implementations, the touch array **310** may be arranged atop a display device **312**. For example, the display device **312** may comprise a liquid crystal display, interferometric display, electronic ink display, and so forth. The combination of the display device **312** and touch array **310** may be referred to as a "touchscreen". In some implementations, the display device **312** may itself include a matrix or array of junctions **308**, such as those used to change the orientation of liquid crystals, to emit light from a light emitting diode junction, and so forth.

During operation, the finger **302** of the user **102** comes into contact with the dielectric material **304**(**1**). Touch sensor circuitry **314** may be configured to measure one or more electrical characteristics associated with one or more junctions **308**. The electrical characteristics may include, but are not limited to, one or more of electrical resistance, electrical capacitance, frequency, or phase. For example, the capacitive touch sensor **108** may measure changes in the electrical capacitance at one or more junctions **308**. The touch sensor circuitry **314** may generate sensor data **230**. For example, the sensor data **230** may comprise time series data **316**. Time series data **316** may be indicative of capacitance at a given

junction **308** at particular times. In some implementations, the time series data **316** may comprise a serialized data stream that is emitted by the touch sensor circuitry **314**.

The touch sensor circuitry **314** may be configured to interleave use of the electrodes **306**. For example, at a first time, the electrodes **306** may be scanned to gather data used to determine a touch. Continuing the example, at a second time, the electrodes **306** may be driven to generate the EMS **122**. In some situations, operation of the touch sensor circuitry **314** may be interleaved with operation of other devices, such as the display device **312**. Continuing the example, the display device **312** may not be driven during one or more of the first time or the second time to minimize interference between the devices.

In some implementations, the touch sensor **108** may be configured to use a far-field capacitance effect that may comprise measuring the self-capacitance of the electrodes **306**, rather than a mutual capacitance. In one implementation, a fixed charge may be provided to one or more of the electrodes **306**, and the resultant voltage may be measured between the one or more of the electrodes **306** and the ground.

In other implementations, the touch sensor **108** may be configured to operate in a mutual capacitance mode, surface capacitance mode, and so forth. In mutual capacitance mode, at least two conductive layers are arranged in a stack with a dielectric material **304** between the layers of the touch array **310**, such as shown in FIG. **3**. The mutual capacitance at points between these layers is measured. When another object touches the outermost conductive layer, the mutual capacitance between the two layers changes, allowing for detection. In surface capacitance mode, voltages are applied to different points of an electrode **306** to produce an electrostatic field. By measuring the changes in current draw (or another electrical characteristic) from the different points at which voltage is applied, a location of an object may be determined.

In another implementation, the touch sensor **108** may measure other electrical characteristics at the junction **308**. For example, instead of a second dielectric material **304**(**2**), the first set of electrodes **306**(**1**) and the second set of electrodes **306**(**2**) may be separated by compressible material that exhibits a change in electrical resistance or conductivity responsive to pressure. In this implementation, the touch sensor circuitry **314** may measure the electrical resistance at the junctions **308** in order to generate time series data **316**.

The portable device **104** may utilize one or more touch sensors **108** that are in a variety of different form factors and sizes. For example, a touchscreen may include a first touch sensor **108**(**1**), while a fingerprint reader comprises a smaller touch sensor **108**(**2**). When the portable device **104** incorporates more than one touch sensor **108**, they may utilize different technologies. For example, the first touch sensor **108**(**1**) may comprise an optical or ultrasonic touch sensor while the second touch sensor **108**(**2**) comprises a capacitive touch sensor. In some implementations, the touch sensor **108** or portion thereof may be configured to acquire fingerprint data. For example, the touch sensor **108** may be configured to scan features of the user's **102** fingerprint.

The touch sensor circuitry **314** may include various devices such as clocks, oscillators, switching electronics to control addressing of the junctions **308**, analog-to-digital converters, filters, digital signal processors, and so forth.

It is possible to use the touch sensor **108** to generate EMS **122**, to receive EMS **122**, or both. When the finger **302** is proximate to a junction **308**, it is capacitively coupled to that junction **308**. This capacitive coupling produces the change in capacitance that is detected by the touch sensor circuitry **314** and used to generate data indicative of a touch event.

The capacitive coupling may be used to transfer a signal from the junction **308** to the finger **302** and thus along the signal path **124** provided by the body of the user **102**. A variety of techniques may be used to produce an EMS **122** using the touch sensor **108**. In one implementation, by driving the junction **308** in a particular fashion, such as by applying a voltage across a particular one of the first set of electrodes **306**(**1**) and the second set of electrodes **306**(**2**), an EMS **122** is generated. In other implementations, the EMS **122** may be generated by providing the time-varying output of an oscillator to a particular junction **308**. In some implementations, one or more of the first set of electrodes **306**(**1**) and one or more of the second set of electrodes **306**(**2**) may be used to generate the EMS **122**. For example, the time varying electrical signal may be applied to all of the first set of electrodes **306**(**1**) and all of the second set of electrodes **306**(**2**). The touch sensor circuitry **314** may be used to drive the touch array **310** to transmit data, such as by driving the junctions **308** in a particular pattern that conveys the first data **120** using on-off-keying (OOK). In other implementations, other modulation or keying techniques may be used by the touch sensor circuitry **314** to generate the EMS **122**. For example, the amplitude of the signals used to scan the junctions **308** of the touch sensor **108** may be varied with time. The time between scans of the junctions **308** may be changed. The phase of the scans may be changed. One or more techniques may be used to generate the EMS **122** and convey data, including, but not limited to, pulse code modulation, pulse width modulation, pulse amplitude modulation, phase modulation, pulse position modulation, pulse duration modulation, pulse frequency modulation, and so forth.

In some implementations, the touch sensor circuitry **314** may include programmable devices, such as a field programmable gate array, field programmable object array, erasable programmable logic device, and so forth. By using these programmable devices, functionality of the system may be modified after deployment without requiring a change in the touch sensor **108** hardware.

The touch sensor **108** may also be used to receive the EMS **122** that is propagated along a signal path **124**. For example, an EMS **122** that is generated by the SFT **128** may be propagated along a signal path **124** of the body of the user **102** to the finger **302**. At the touch array **310**, the touch sensor circuitry **314** may generate sensor data **230** responsive to the EMS **122**. For example, the EMS **122** may produce at the junction **308** a change in one or more electrical characteristics which may be measured by the touch sensor circuitry **314**. The touch sensor circuitry **314** may interpret this change as a touch event. The time series data **316** may be indicative of touch events and particular patterns, or with a particular repetition rate. For example, the EMS **122** as detected by the touch sensor **108** may generate time series data **316** that is indicative of 27 touches per second. This time series data **316** may then be processed by the data processing module **232** to decode the second data **130** that was transmitted by the SFT **128**. For example, the second data **130** may be transmitted by the SFT **128** using OOK. The time series data **316** may be processed to look for touch events that correspond to particular patterns, occur within certain windows of time, and so forth.

In some implementations, the display device **312** may be used to generate EMS **122**. As described above, the display device **312** may itself have an array of junctions **308**. For

example, a light emitting diode (LED) display may comprise an array of thousands of picture elements (pixels) that each comprise one or more diode junctions **308**. By energizing particular pixels, an image is produced on the LED display. During activation of a particular diode junction **308**, an EMS **122** may be omitted. By controlling which pixels are energized, and the time at which they are energized, it is possible to generate an EMS **122** that conveys data. In one implementation, a particular image or sequence of images may be presented by the display device **312** to generate a particular EMS **122**. For example, the sequence of images that alternate some number of all-black frames with some number of all-white frames may be used to generate the EMS **122**. The EMS **122** may then be capacitively coupled to the finger **302** and thus pass along the signal path **124** to a receiver, such as that in the SFT **128**.

In some implementations, the touch array **310** or portion thereof may be used as an antenna for the EMS transceiver **214**. For example, the output from the transmitter of the EMS transceiver **214** may be connected to the first set of electrodes **306**(**1**).

The user **102** may be instructed to maintain contact with the touch sensor **108** at a specific time to facilitate transmission of the transferred data **126**. For example, the display device **312** may be directed to present an icon or image that directs the user **102** to touch the touch sensor **108**. While that icon is being presented, the EMS **122** may be generated and used to transmit the transferred data **126** between the portable device **104** and the SFT **128**.

FIG. **4** illustrates a block diagram **400** of a smart floor tile **128**, according to some implementations. A side view of a portion of the SFT **128** depicts a top layer comprising a protective material, such as flooring material **402**. The flooring material **402** is electrically non-conductive under ordinary conditions. For example, the flooring material **402** may include plastic, ceramic, wood, textile, or other material. Beneath a layer of flooring material **402** may be one or more antennas **404** and one or more sensors **106**. The antennas **404** may comprise structures designed to accept or emit EMS **122**. In some implementations, the antennas **404** may also serve as the flooring material **402**. For example, the antennas **404** may comprise aluminum or steel sheets upon which the users **102** walk. The active portion of the antenna **404** comprises that portion of the antenna **404** that is used to radiate or receive an EMS **122**.

The SFT **128** may include a plurality of antennas **404**. For example, the antennas **404** may be arranged to form an array. In some implementations, the active portion of the antennas **404** may have a surface area that occupies at least 1 square inch. Each segment of the SFT **128** includes at least one segment antenna **404**. The segment antenna **404** of the segment may be the same size as the segment or may be smaller. For example, the segment may be 4 inches by 4 inches square, but the segment antenna **404** in that segment may only be 2 inches by 2 inches square. In another example, the segment may be 4 inches by 4 inches square and the segment antenna **404** in that segment may be 4 inches by 4 inches square. Each segment antenna **404** may have a maximum size of sixteen square inches, in some implementations. The size of the segment antennas **404** may be determined at least in part based on the expected size of the objects in contact with the floor, such as the size of the foot of the user **102**. In one implementation, antennas **404** may be shared, with a single antenna **404** being used to both transmit and receive either simultaneously or at different times. In another implementation, separate antennas **404** may be used to transmit and receive.

The SFT **128** may also include a plurality of sensors **106** that may be arranged to form one or more arrays. For example, the sensors **106** may include weight sensors that measure the weight applied to a particular segment. The sensors **106** provide sensor output data. The arrangement of an array of one type of sensor **106** may differ from another type of sensor **106**. In some implementations, the sensors **106** may include a magnetometer that provides information about local magnetic fields.

As illustrated here, the antennas **404** may be located within a common plane. In other implementations, the antennas **404** may be arranged within a layer **406** that is above the sensors **106**, below the sensors **106**, and so forth. A load bearing support structure **408** may be beneath the sensors **106** and the antennas **404** and provides mechanical and physical separation between the underlying subfloor **410** upon which the SFT **128** rests and the flooring material **402**. The support structure **408** may comprise a series of pillars, posts, ribs, or other vertical elements. The support structure **408** may comprise a composite material, plastic, ceramic, metal, or other material. In some implementations, the support structure **408** may be omitted, and electronics **412** or structures associated with the electronics **412** may be used to support a load on the flooring material **402**. For example, the electronics **412** may comprise a glass fiber circuit board that provides mechanical support while also providing a surface for mounting the electronics **412**. The subfloor **410** may comprise concrete, plywood, or existing flooring materials over which the SFT **128** is installed. In some implementations, the SFT **128** may be affixed to the subfloor **410**, or may be unaffixed or "floating". For example, the SFT **128** may be adhered to the subfloor **410** using a pressure sensitive adhesive.

The SFT **128** includes the electronics **412**. The electronics **412** may include the elements described elsewhere in more detail. In the implementation depicted here, the electronics **412** are arranged within the support structure **408**. In some implementations, one or more of the antennas **404** or the sensors **106** may be located within the support structure **408**. The support structure **408** may operate as a heat sink to dissipate heat generated by operation of the electronics **412**.

The SFT **128** may incorporate a wiring recess **414** on an underside of the SFT **128**. For example, the support structure **408** and the electronics **412** may be formed or arranged to provide a pathway for a wiring harness **416** to pass beneath at least a portion of the SFT **128**. The wiring recess **414** may extend from one edge of the SFT **128** to another, may extend in different directions, and so forth. For example, the wiring recess **414** may be arranged in a "+" or cross shape, allowing for wiring harnesses **416** to pass along the X or Y axes as depicted here.

The wiring harness **416** may provide a coupling to one or more of the power supply **418**, a network, and so forth. For example, the wiring harness **416** may include conductors that allow for the SFT **128** to receive electrical power from an electrical distribution network, allow for connection to a CAN bus network that services a cluster of SFTs **128**, and so forth. The wiring harness **416** may include electrical conductors, electromagnetic waveguides, fiber optics, and so forth. In some implementations, a plurality of wiring harnesses **416** may be used. For example, a first wiring harness **416**(**1**) may provide electrical power while a second wiring harness **416**(**2**) provides network connectivity. In some implementations, the wiring harness **416** may be used to provide information that is then processed to determine a relative arrangement of SFTs **128**.

The electronics **412** of the SFT **128** may include a power supply **418**. The power supply **418** may include an electric power interface that allows for coupling to a power distribution system. For example, the electrical power interface may comprise connectors, voltage converters, frequency converters, and so forth. The power supply **418** may include circuitry that is configured to provide monitoring or other information with regard to the consumption of electrical power by the other electrical power components of the SFT **128**. For example, the power supply **418** may include power conditioning circuitry, DC to DC converters, current limiting devices, current measurement devices, voltage measurement devices, and so forth. In some implementations, the SFT **128** may be configured to connect to redundant power buses. For example, a first electrical distribution network such as an "A" bus and a second electrical distribution network such as a "B" bus may be provided, each of which can provide sufficient electrical power for operation. In some implementations, the SFT **128** may incorporate redundant power supplies **418**.

The SFT **128** may include one or more hardware processors **420**. The hardware processors **420** may include microprocessors, microcontrollers, systems on a chip (SoC), field programmable gate arrays (FPGAs), and so forth. The SFT **128** may also include one or more memories **422**. The memory **422** may comprise one or more non-transitory CRSM. The CRSM may be any one or more of an electronic storage medium, a magnetic storage medium, an optical storage medium, a quantum storage medium, a mechanical computer storage medium, and so forth. The memory **422** provides storage of computer-readable instructions, data structures, program modules, and other data for the operation of the SFT **128**.

The SFT **128** may include electronics **412**. The electronics **412** may be configured to acquire information from sensors **106** of the SFT **128**, process that information, and so forth. In one implementation, the sensors **106** may comprise electrodes or other electrically conductive elements that are used as part of a capacitive sensor array. In one implementation, the electrodes may be arranged in an array. Each electrode may be rectangular with a first side and a second side, with the length of the first side and the second side being between 10 millimeters and 50 millimeters. In other implementations, other shapes and sizes of electrodes may be used.

The electronics **412** may include capacitance measurement circuitry that generates capacitance data. The capacitance measurement circuitry may use various techniques to determine capacitance. For example, the capacitance measurement circuitry may include a source that provides a predetermined voltage, a timer, and circuitry to measure voltage of the conductive element relative to the ground. By determining an amount of time that it takes to charge the conductive element to a particular voltage, the capacitance may be calculated. The capacitance measurement circuitry may use one or more of analog or digital circuits to determine capacitance. During operation, the capacitive sensor uses a conductive element located beneath the flooring material **402** to produce capacitance data indicating capacitance values at particular times. Based on the capacitance data, information such as a presence of an object, shape of an object, and so forth, may be generated to produce sensor output data **424**. The sensor electronics **412** may be configured to scan the sensors **106** and generate sensor output data **424** at least 40 times per second. The sensor output data **424** may include information about proximity of an object with respect to a particular electrode. The sensor output data **424** may be further processed to generate the other data.

In other implementations, the sensors **106** may comprise optical touch sensors **108** comprising one or more illuminators and one or more photodetector elements, resistive touch sensors **108** comprising electrically resistive material, acoustic touch sensors **108** comprising one or more transducers, and so forth. The sensors **106** may include other sensors, such as a weight sensors, moisture detectors, microphones, and so forth.

The SFT **128** may include a receiver **426**. The receiver **426** is configured to detect the EMS **122**. The receiver **426** may be implemented as discrete circuitry, as a software defined radio (SDR), and so forth. The receiver **426** is coupled to one or more of the antennas **404**. In some implementations, a single receiver **426** may be coupled to a single antenna **404**. In other implementations, a single receiver **426** may be coupled to a plurality of antennas **404** by way of switching circuitry, matching network, and so forth. The switching circuitry may allow the selective connection of a particular antenna **404** to the receiver **426**. The receiver **426** may be configured to detect the EMS **122** at a particular frequency and generate information indicative of a received signal strength.

In some implementations, elements of the sensors **106** may be combined or used in conjunction with the antennas **404**. For example, electrically conductive elements may be used for both capacitive sensing by the sensor **106** and as antennas **404**. This dual use may occur at the same time or may be multiplexed over time. For example, switching circuitry may, at a first time, selectively connect the sensor electronics **412** to the electrically conductive element for use as a capacitive sensor pad. The switching circuitry may then selectively connect, at a second time, the receiver **426** to the same electrically conductive element for use as an antenna **404**.

The EMS **122** is acquired by the antenna **404** and then provided to the receiver **426**. For example, the receiver **426** may comprise a superheterodyne receiver, with an incoming radio signal being converted to an intermediate frequency by a mixer. At the intermediate frequency stage, the downconverted signal is amplified and filtered before being fed to a demodulator. One or more antennas **404** may be dedicated for use by the receiver **426**, while one or more other antennas **404** may be dedicated for use by the transmitter(s) **428**. The use of separate antennas **404** to transmit and receive may improve isolation between the receiver **426** and the transmitter **428**. The receiver **426** or the hardware processor **420** processes the EMS **122** to determine the characteristic data **136**, such as a received frequency and the signal strength received at that frequency. In another implementation, the receiver **426** may comprise an SDR.

In some implementations, the EMS **122** may convey data. The receiver **426** or the hardware processor **420** may decode, decrypt, or otherwise demodulate and process the demodulated signal to determine the characteristic data **136**. For example, the receiver **426** may provide as output the digital representation of a signal that incorporates binary phase shift keying (BPSK) or other techniques. The hardware processor **420** may process this digital representation to recover a serial data stream that includes framing, error control data, payload, and other information. The payload may then be processed to produce output. The error control data may include error detection data such as parity check data, parity bits, hash values, and so forth. For example, a hash function may be applied to the characteristic data **136** to generate

hash output. A comparison of the hash output may be made to determine if an error is present.

The SFT **128** includes one or more transmitters **428**. For example, the transmitter **428** may comprise a voltage controlled oscillator that generates an output signal that is fed directly to a power amplifier. The transmitter **428** couples to an antenna **404**, which then radiates the EMS **122**. The transmitter **428** may be implemented as discrete circuitry, SDR, or a combination thereof.

The transmitter **428** may accept multiple signals to generate the EMS **122** that is emitted from an antenna **404** connected to the output of the transmitter **428**. In some implementations, each segment of the SFT **128** may utilize a single transmitter **428** that produces an EMS **122** that includes at least the segment signal. In other implementations, a single transmitter **428** may be used to generate all of the EMS **122** from a given SFT **128**. For example, the transmitter **428** may generate the initial signal and all the respective segment signals for that SFT **128**. Filters may be used on the output such that the antenna **404** at a particular segment emits only the desired frequency associated with that particular segment.

The transmitter **428** may be configured to produce an EMS **122** that is amplitude modulated, frequency modulated, phase modulated, and so forth. The transmitters **428** for the SFTs **128** in a given floor may operate on a single frequency, or may be frequency agile and operate on a plurality of different frequencies. For example, at a first time, a single transmitter **428** may generate the segment signals at a first frequency and then transition to transmitting at a second frequency. In some implementations, the receiver **426** and the transmitter **428** may be combined or share one or more components. For example, the receiver **426** and the transmitter **428** may share a common oscillator or frequency synthesizer.

In some implementations, a single antenna **404** may be used to both transmit and receive. For example, the receiver **426** may include notch filters to attenuate the frequencies of the transmitted EMS **122**. A single antenna **404** may also be used to transmit different signals. For example, a single antenna **404** may be used to transmit the initial signal and a segment signal. In some implementations, a diplexer may be used that accepts input from two or more transmitters **428** and provides output of the EMS **122** to an antenna **404** or group of antennas **404**. In other implementations, the diplexer or other filtering may be omitted, and one or more transmitters **428** may be coupled to a single antenna **404** or group of antennas **404**.

The hardware processor **420** may acquire data from one or more of the sensors **106**, the receiver **426**, the transmitter **428**, and so forth, to generate other data **430**. The other data **430** comprises information about an object that is resting on or proximate to the flooring material **402**. The information may be indicative of a shape of the object. In some implementations, the other data **430** may comprise information that is representative of the contours of an object. For example, the other data **430** may comprise a bitmap representative of the output from a plurality of sensors **106** and indicative of their relative arrangement. In another example, the other data **430** may comprise a vector value that is indicative of polygons used to represent an outline of an object. In some implementations, the other data **430** may be indicative of an area of the object. For example, the other data **430** may indicate that the total area of an object is 48 square centimeters. The other data **430** may include other information such as information about amplitude of a received EMS **122** with respect to different portions of the object. For example, other data **430** may be generated that indicates the shape of the object with information about amplitude, frequency, or other details about the EMS **122** at particular points or areas within that shape.

In some implementations, one or more of the receiver **426** or the transmitter **428** may be used to generate the sensor output data **424**. For example, sensors **106** may communicate with the power supply **418** to determine the amount of electrical current that is being drawn at a particular time by the transmitter **428**. As the electrical coupling between an object above the SFT **128** and one or more of the antennas **404** changes, one or more operating characteristics of the devices in the SFT **128** may change. For example, the impedance of the antenna **404** may experience change. Changes in the impedance may result in a change in the power output of the transmitter **428** during operation. For example, the transmitter **428** may exhibit an impedance mismatch with the antenna **404** in the presence of an object, such as a foot. This impedance mismatch may result in reduced power consumption by the radio frequency amplifier of the transmitter **428**. Information about changes in the operational characteristics, such as a change in current draw by the transmitter **428**, may be processed to determine the presence or absence of an object with respect to the antenna **404**. The operating characteristics may include, but are not limited to: received signal strength at the receiver **426**, power consumption of the transmitter **428**, radio frequency power output of the transmitter **428**, impedance presented at an antenna **404**, standing wave ratio (SWR), and so forth. For example, the impedance of the antenna **404** may be measured at a radio frequency input to the receiver **426**, a radio frequency output of the transmitter **428**, and so forth. In another example, the SWR presented by one or more of the antennas **404** may be similarly measured. In other implementations, other operating characteristics may be used. For example, a change in the noise detected by the receiver **426** may be used to determine presence or absence of an object. In yet another implementation, the transmitter **428** of the SFT **128** may generate a signal that is then received by the receiver **426** of the same SFT **128**. A change in the received signal at a particular antenna **404** may be used to determine the presence of an object. In still another implementation, the EMS **122** received from the other SFT **128** may be measured, and the received signal strength at particular segments may be used to generate information indicative of the presence of an object.

By combining information from a plurality of antennas **404**, other data **430** may be generated. In other implementations, other characteristics of the receiver **426** or the transmitter **428** may be assessed to generate the other data **430** or other information indicative of proximity of an object to the antenna **404**. For example, the change in impedance may be measured, a change in background noise level may be measured, and so forth. In some implementations, radio ranging may be utilized in which the transmitter **428** emits a pulse and the receiver **426** listens for a return or echo of that pulse. Data indicative of proximity from several antennas **404** may then be processed to generate the other data **430**. In another implementation, distance between the object and the antenna **404** may be determined using the amplitude of the received EMS **122**. For example, a lookup table may be used that associates a particular received signal strength with a particular distance from the antenna **404**.

The communication interface **432** connects the SFT **128** to a network. For example, the communication interface **432** may be able to connect to one or more of a CAN bus, Inter-Integrated Circuit (I2C), Serial Peripheral Interface

bus (SPI), 1-Wire bus, Universal Serial Bus (USB) as promulgated by the USB Implementers Forum, RS-232, Ethernet, Wi-Fi, Bluetooth, and so forth. The communication may be facilitated by data connectors, such as optical connectors, electrical connectors, and so forth. The data connectors provide a pathway for signals to be exchanged between the communication interface **432** and the network.

The SFT **128** may include non-transitory computer readable media that is used to store instructions, data, and so forth. Tile identifier data **434** comprises information indicative of a particular SFT **128**. The tile identifier data **434** may be unique within the particular network, the facility, unique across the production of all SFTs **128** manufactured, and so forth. In some implementations, a media access control (MAC) address, network address, bus address, and so forth, that is associated with the communication interface **432** may be used as tile identifier data **434**.

During operation, the hardware processor **420** may generate tile output data **134**. As described above, the tile output data **134** may include the characteristic data **136**. In some implementations, the tile output data **134** may indicate the characteristic data **136** that was received by the SFT **128**, the particular antennas **404** or segments associated with that reception, information about the frequencies of EMS **122** that are being transmitted, and so forth. The tile output data **134** may also include the tile identifier data **434**, timestamp data, and so forth. For example, the timestamp data included in the tile output data **134** may indicate when the characteristic data **136** was received by the receiver **426**.

The SFT **128** may include multiple hardware processors **420** with different capabilities. For example, individual elements of the sensors **106** may utilize dedicated state machines to perform simple processing functions. These dedicated state machines may then send output data to a microcontroller that provides additional processing to generate sensor output data **424**. In one implementation, the dedicated state machine may comprise a complex programmable logic device (CPLD). Continuing the example, a dedicated state machine may provide a 4 bit value indicative of the capacitance measured by a capacitive sensor **106** at a particular location on the SFT **128**. The microcontroller may have information that describes a relative arrangement of the sensors **106**, and may use this information in conjunction with the dedicated state machine output to generate a bitmap that may be included in the other data **430**.

Various techniques may be used to increase the overall uptime of an individual SFT **128**, and functionality of the floor as a whole. In one implementation, the SFT **128** may include additional components to provide for failover redundancy. For example, the SFT **128** may include at least two hardware processors **420**, each of which is able to generate other data **430**, generate tile output data **134**, and so forth. In another example, the SFT **128** may include two power supplies **418**, each connected to a different bus or power supply.

To provide additional redundancy, adjacent SFTs **128** may be connected to different networks. For example, an SFT **128** may be connected to a first network **110** while the SFT **128** immediately to the right may be connected to a second network **132**.

The SFT **128** may be configured to perform diagnostics of onboard components, adjacent SFTs **128**, and so forth. For example, the SFT **128** may be configured to test the receiver **426** and the transmitter **428** by transmitting a signal from the first antenna **404**(**1**) and listening with the receiver **426** using a second antenna **404**(**2**) that is adjacent to the first antenna **404**(**1**). In some implementations, the SFT **128** may be configured to send diagnostic data using the network. For example, diagnostic data may be sent to the inventory management system **114** indicating that a particular SFT **128** has a fault and requires repair or replacement. The SFT **128** may be designed in a modular fashion to allow for repair or replacement without affecting adjacent SFTs **128**.

In some implementations, operation of the SFT **128** or the segments therein may be responsive to presence or absence of an object. For example, segments that are proximate to or underneath the object forming a shape may be deemed active segments. Antennas **404** associated with these active segments may be used to transmit or receive the EMS **122**. Inactive segments comprise segments that are not underneath or proximate to the object. The determination of whether a segment is active or not may be based at least in part on output from the sensor elements, antennas **404**, or other sensors. For example, a segment may be deemed to be an active segment when the associated sensor element exhibits a capacitance value that exceeds a threshold level.

During operation, the determination of which segments are active may be used to determine which antennas **404** are used to one or more of transmit or receive the EMS **122**. For example, the antennas **404** beneath inactive segments may be disconnected from receivers **426**, or the receivers **426** associated with those antennas **404** may be placed in a low power mode or turned off. As an object is detected by the sensor element as driven using the electronics **412**, a particular segment may be designated as an active segment. In this illustration, the active segments are represented with a crosshatch pattern. The antenna **404** and associated radio frequency elements such as the receiver **426** and the transmitter **428** associated with that antenna **404** may be transitioned to an operational mode. For example, the receiver **426** may begin listening for an EMS **122**.

The SFT **128**, or portions thereof such as segments, may transition from a receive mode to a transmit mode or vice versa. This transition may be responsive to the detection of an object by the sensor **106**. For example, the presence of an object followed by the absence of the object may result in the SFT **128** transitioning from the transmit mode to the receive mode.

By selectively transmitting the EMS **122** using antennas **404** that are within a threshold distance of the shape as determined by the sensors **106**, performance of the system may be improved. For example, power consumption may be reduced by transmitting using only those antennas **404** that are proximate to the object producing the shape. In other implementations, the transmitters **428** may be activated on a particular schedule, such as transmitting for 50 milliseconds duration with a gap waiting time of 100 ms before the next transmission. This reduction in duty cycle decreases power consumption.

In some implementations, segments may be in transmit mode while the receiver **426** is still active. For example, the transmitters **428** may transmit while the receiver **426** is listening.

The sensors **106** in the SFT **128** may be used to determine the presence of hazardous conditions at the SFT **128**. For example, the sensors **106** may be able to detect a liquid that is present on the flooring material **402** that may comprise a slipping hazard. Continuing the example, a puddle of water on the flooring material **402** may be detected. Information indicative of the puddle may be provided to the inventory management system **114** for mitigation, such as clean up. In another example, the sensors **106** may be able to detect a user **102** lying on the flooring material **402**. Upon such detection, an attendant of the facility may be alerted to

provide assistance to the user **102**. With this example, the floor provides information to the operators of the facility that may be used to improve the safety of the facility for the users **102**.

FIG. **5** depicts a flow diagram **500** of a process of the portable device **104** using a touch sensor **108** to generate EMS **122** to communicate with an SFT **128**, according to some implementations. The process may be implemented at least in part by the portable device **104**.

At **502**, first data **120** is accessed. In some implementations, the first data **120** may be generated by the portable device **104**. For example, a biometric sensor **106**(**1**) may be used to acquire biometric data about the user **102**. The first data **120** may be based at least in part on the biometric data. For example, the biometric data may be compared with data previously stored on the portable device **104**, or may be provided to an authentication module **116** to generate authentication data. The biometric data may comprise fingerprint data obtained from a fingerprint reader. In some implementations, the first data **120** may comprise a token or value that is indicative of a particular authentication session or task.

In other implementations, the first data **120** may comprise user input data that is obtained by the touch sensor **108**. For example, the user input data may be indicative of an identity, such as password, PIN number, or other secret information using the touch sensor **108**. The first data **120** may be generated based at least in part on the user input data, such as a hash of the password entered by the user **102**. In another implementation, the user input data may be encrypted or otherwise used as an input to a function or module that then generates the first data **120**.

At **504**, the touch sensor circuitry **314** is operated to generate a first EMS **122**. For example, the capacitive sensor circuitry in a capacitive touch sensor **108** may be configured to apply a particular voltage to one or more particular electrodes **306** at particular times, such that the first data **120** is conveyed by the resulting EMS **122**.

At **506**, the first EMS **122** is coupled to the user **102**. For example, the finger **302** of the user **102** may be capacitively coupled to one or more of the electrodes **306** in the touch array **310**.

At **508**, the first EMS **122** is propagated to an SFT **128** via a signal path **124** that incorporates the user **102**. For example, the EMS **122** may be of a frequency that is passed via skin effect along the surface of the user **102**.

At **510**, the SFT **128** receives the first EMS **122**. For example, the receiver **426** in the SFT **128** is connected to an antenna **404** that is also electromagnetically coupled to the user **102**. The receiver **426** may then receive the first EMS **122**.

At **512**, the first data **120** is determined using the first EMS **122**. For example, the first EMS **122** may be decoded to provide the first data **120**. Continuing the earlier example, the first data **120** may comprise authentication data. In some implementations, the SFT **128** may send the first data **120**, or data based at least in part thereon, to the server **112**.

By using this technique, the ability to generate EMS **122** and provide for the communication described herein is enabled without the need for dedicated hardware, such as the EMS transceiver **214**. As a result, significant benefits are realized such as a reduced cost for bill of materials, assembly costs, and so forth, consistent with a reduction in overall parts count. Furthermore, existing portable devices **104** may be provided with executable instructions that allow for this functionality using their existing hardware.

FIG. **6** depicts a flow diagram **600** of a process of the portable device **104** using a touch sensor **108** to receive EMS **122** transmitted by an SFT **128**, according to some implementations. The process may be implemented at least in part by the portable device **104**.

At **602**, the SFT **128** accesses second data **130**. For example, the second data **130** may comprise a token, or other value generated by the SFT **128** or received from the server **112**. For example, the SFT **128** may generate a value that is based at least in part on the unique identifier associated with the SFT **128**.

At **604**, the SFT **128** transmits a second EMS **122** that conveys the second data **130**. For example, the transmitter **428** of the SFT **128** may generate a signal that is radiated by an antenna **404** that is connected to the transmitter **428**.

At **606**, the second EMS **122** is coupled to the user **102**. For example, the foot of the user **102** may be capacitively coupled to the antenna **404** of the SFT **128**.

At **608**, the second EMS **122** is propagated to the portable device **104** via a signal path **124** that incorporates the user **102**.

At **610**, the touch sensor circuitry **314** is operated to determine the time series data **316**. As described above, the time series data **316** may be indicative of changes in one or more electrical characteristics at one or more of the electrodes **306** of the touch sensor **108**. For example, the time series data **316** may comprise timestamps and the addresses indicative of particular junctions **308** and changes in one or more electrical characteristics for each of those junctions **308** that are associated with the perspective timestamps.

At **612**, the second data **130** is determined based on the time series data **316**. For example, the time series data **316** may be indicative of "phantom" or electronically induced touch events that are responsive to the second EMS **122**. Continuing the example, the second EMS **122** may be modulated using on-off keying (OOK) to convey the second data **130**. In some implementations, the second data **130** may comprise authentication data, or other information.

Communication between the portable device **104** and the SFT **128** may be unidirectional or bidirectional. For example, the SFT **128** may emit EMS **122** and the portable device **104** receives those EMS **122** and determines the second data **130** conveyed therein. In another example, the portable device **104** transmit the first EMS **122**(**1**) and the SFT **128** may transmit the second EMS **122**(**2**). By utilizing the communication, either unidirectional or bidirectional, between the portable device **104** and the SFT **128**, data may be exchanged that is subsequently used to associate a particular user **102** with a particular location, such as that of the SFT **128**. By using biometric data, physical presence of the user **102** at a particular location may be assured at a particular time.

By using this technique, the ability to receive the EMS **122** and provide for the communication described herein is enabled without the need for dedicated hardware, such as the EMS transceiver **214**. As a result, significant benefits are realized such as a reduced cost for bill of materials, assembly costs, and so forth, consistent with a reduction in overall parts count.

FIG. **7** depicts a flow diagram **700** of a process of the portable device **104** using a display device **312** to generate EMS **122** to communicate with an SFT **128**, according to some implementations. The process may be implemented at least in part by the portable device **104**. Furthermore, existing portable devices **104** may be provided with executable instructions that allow for this functionality using their existing hardware.

At **702**, first data **120** is accessed. As described above, the first data **120** may be generated by the portable device **104**, by the server **112**, or a combination of the two.

At **704**, the display device **312** is operated to generate a first EMS **122**. For example, one or more of the voltage or amperage used to drive a pixel within the display device **312** may be increased for a specified period of time. In some implementations, the voltage or amperage may exceed the normal operating specifications for the elements of the pixel, however this surge may be for a duration of time that is short enough to prevent damage to the elements of the pixel. In other implementations, one or more of the pixels may be driven between particular states, such as off-and-on at particular times in order to generate the EMS **122**.

At **706**, the first EMS **122** is coupled to the user **102**. For example, the finger **302** of the user **102** that is in contact with or proximate to the display device **312** may be capacitively coupled to one or more of the electrodes **306**, transistors, diodes, or other elements that the pixels in the display device **312** comprise.

At **708**, the first EMS **122** is propagated to an SFT **128** via a signal path **124** that incorporates the user **102**. For example, the EMS **122** may be of a frequency that is passed via skin effect along the surface of the user **102**.

At **710**, the SFT **128** receives the first EMS **122**. For example, the receiver **426** in the SFT **128** is connected to an antenna **404** that is also electromagnetically coupled to the user **102**. The receiver **426** may then receive the first EMS **122**.

At **712**, the first data **120** is determined using the first EMS **122**. For example, the first EMS **122** may be decoded to provide the first data **120**. Continuing the earlier example, the first data **120** may comprise authentication data. In some implementations, the SFT **128** may send the first data **120**, or data based at least in part thereon, to the server **112**.

By using this technique, the display device **312** may be used to generate the EMS **122**, facilitating an extremely localized communication pathway, suitable for the exchange of information such as authentication data.

FIG. **8** depicts a diagram **800** of a portable device with a cover that includes one or more of a transmitter or a receiver to provide communication with a smart floor tile **128**, according to some implementations.

A front view **802** and a side view **804** are presented. A cover **806** comprises an accessory that may be attached to the portable device **104**. For example, the cover **806** may comprise mechanical, magnetic, or other types of fastener that joins the two. The cover **806** may include one or more of the elements described above with regard to the portable device **104**. For example, the cover **806** may include a power supply **202**, or mechanisms to draw power from the portable device **104**, may include an EMS transceiver **214**, and so forth. The cover **806** may include one or more antennas that are connected to the EMS transceiver **214**. During operation, the cover **806** may be used to transmit EMS **122**, receive EMS **122**, or both. The cover **806** allows the functionality described herein to be provided to the portable device **104**. In some implementations, the cover **806** may provide other functionalities. For example, the cover **806** may include a battery to provide power to the portable device **104**, photovoltaic cells, sensors **106**, and so forth.

FIG. **9** depicts a flow diagram **900** of a process of authenticating a user **102** that includes a transfer of data between the portable device **104** and the smart floor tile **128**, according to some implementations. The process may be implemented at least in part by one or more of the portable device **104**, the SFT **128**, the server **112**, and so forth.

At **902**, the portable device **104** acquires sensor data **230** indicative of biometric input. For example, the user **102** may place a finger **302** on a fingerprint reader that then generates fingerprint data. In another example, the user **102** may look at a camera that acquires an image of their face, iris, ears, and so forth.

At **904**, the portable device **104** generates authentication request data. For example, the authentication request data may comprise a hash, encrypted value, or other information that is based at least in part on the fingerprint data. At **906**, the authentication request data is then sent from the portable device **104** to the server **112**. For example, the portable device **104** may use a network interface **212** to send the authentication request data **906** to the server **112**.

At **908**, the server **112** generates authentication data. For example, the authentication module **116** may process the authentication request data **906** to determine if the fingerprint data matches the value that has been previously stored in the account data **118**. When a match is determined, authentication data is generated that may comprise a token, value, or other information indicative of a particular user account that is indicated by the account data **118**.

At **910**, the authentication data is sent from the server **112** to the portable device **104**. For example, the server **112** may use a network interface **212** to send the authentication data to the portable device **104**.

At **912**, the portable device **104** generates an EMS **122** that conveys the authentication data, or information based at least in part on the authentication data.

At **914**, the EMS **122** is transmitted from the portable device **104** via the signal path **124** to the SFT **128**. For example, the EMS **122** may be generated by one or more of the touch sensor **108**, the display device **312**, the EMS transceiver **214**, and so forth.

At **916**, the SFT **128** receives and processes the EMS **122** and generates received authentication data.

At **918**, the SFT **128** sends the received authentication data to the server **112**. For example, the SFT **128** may use the communication interface **432** and transmit the received authentication data to the server **112** using the second network **132**.

At **920**, based on the authentication data and the received authentication data, the server **112** determines the user account that is associated with the portable device **104**. The received authentication data may be used to search the account data **118** to determine a particular user account. The authentication data that was previously generated and associated with the particular user account may then be retrieved. The authentication data that was originally generated and sent to the portable device **104** may then be compared to the received authentication data that was sent to the SFT **128**. If the comparison indicates a match that exceeds a threshold value, the user **102** may be authenticated to the particular user account.

In some implementations, the process may be modified in a variety of ways. For example, the authentication data may be transmitted using the EMS **122** and provided to the SFT **128**. The SFT **128** may then communicate with the server **112** to determine if the authentication data (such as fingerprint data) transmitted via the EMS **122** corresponds to a particular user account.

In another implementation, the SFT **128** may generate a value, that is transmitted using the EMS **122**. The value may be one that is specific to a particular SFT **128**, that changes with time, and so forth. The SFT **128** may send that value to the server **112**, or the server **112** may use the same algorithm and based on the same initialization vector as the SFT **128**

may generate the same value locally. The portable device **104** may obtain biometric data about the user **102**, and send data based at least in part on the biometric data to the server **112**. The portable device **104** may also obtain the value transmitted by the SFT **128**. The server **112** may determine if the value received from the SFT **128** as obtained by the portable device **104** matches that which was known to have been sent by the SFT **128**. In the event of a match, the particular user account associated with the biometric data may be authenticated to the user **102**.

It is recognized that other implementations may be used to take advantage of the localized communication between the SFT **128** and the portable device **104** as afforded by the EMS **122**. By using this localized communication with devices such as the SFT **128** which is located at the facility, biometric data, user input data, or other information may be obtained by the portable device **104** and associated with a particular user **102** who is present at the facility.

FIG. **10** is a block diagram **1000** illustrating a materials handling facility (facility) **1002** using the system **100**, according to some implementations. A facility **1002** comprises one or more physical structures or areas within which one or more items **1004**(**1**), **1004**(**2**), . . . , **1004**(Q) may be held. The items **1004** may comprise physical goods, such as books, pharmaceuticals, repair parts, electronic gear, and so forth.

The facility **1002** may include one or more areas designated for different functions with regard to inventory handling. In this illustration, the facility **1002** includes a receiving area **1006**, a storage area **1008**, and a transition area **1010**. Throughout the facility **1002**, the plurality of SFTs **128** may be deployed as described above.

The receiving area **1006** may be configured to accept items **1004**, such as from suppliers, for intake into the facility **1002**. For example, the receiving area **1006** may include a loading dock at which trucks or other freight conveyances unload the items **1004**. In some implementations, the items **1004** may be processed, such as at the receiving area **1006**, to generate at least a portion of item data as described below. For example, an item **1004** may be tested at the receiving area **1006** to determine the attenuation of an EMS **122** passing through it, and this information stored as item data.

The storage area **1008** is configured to store the items **1004**. The storage area **1008** may be arranged in various physical configurations. In one implementation, the storage area **1008** may include one or more aisles **1012**. The aisle **1012** may be configured with, or defined by, the fixtures on one or both sides of the aisle **1012**. The fixtures may include one or more of a shelf, a rack, a case, a cabinet, a bin, a floor location, or other suitable storage mechanisms for holding, supporting, or storing the items **1004**. For example, the fixtures may comprise shelves with lanes designated therein. The fixtures may be affixed to the floor or another portion of the structure of the facility **1002**. The fixtures may also be movable such that the arrangements of aisles **1012** may be reconfigurable. In some implementations, the fixtures may be configured to move independently of an outside operator. For example, the fixtures may comprise a rack with a power source and a motor, operable by a computing device to allow the rack to move from one location within the facility **1002** to another.

One or more users **102** and totes **1014** or other material handling apparatus may move within the facility **1002**. For example, the user **102** may move about within the facility **1002** to pick or place the items **1004** in various fixtures, placing them on the tote **1014** for ease of transport. The tote **1014** is configured to carry or otherwise transport one or more items **1004**. For example, the tote **1014** may include a basket, cart, bag, bin, and so forth. In other implementations, other material handling apparatuses such as robots, forklifts, cranes, aerial drones, and so forth, may move about the facility **1002** picking, placing, or otherwise moving the items **1004**. For example, a robot may pick an item **1004** from a first fixture and move the item **1004** to a second fixture.

One or more sensors **106** may be configured to acquire information in the facility **1002**. The sensors **106** may include, but are not limited to, weight sensors **106**(**2**), image sensors **106**(**3**), depth sensors **106**(**4**), and so forth. The sensors **106** may be stationary or mobile, relative to the facility **1002**. For example, the fixtures may contain weight sensors **106**(**2**) to acquire weight sensor data of items **1004** stowed therein, image sensors **106**(**3**) to acquire images of picking or placement of items **1004** on shelves, optical sensor arrays **106**(**13**) to detect shadows of the user's **102** hands at the fixtures, and so forth. In another example, the facility **1002** may include image sensors **106**(**3**) to obtain images of the user **102** or other objects in the facility **1002**. The sensors **106** are discussed in more detail below with regard to FIG. **11**.

While the storage area **1008** is depicted as having one or more aisles **1012**, fixtures storing the items **1004**, sensors **106**, and so forth, it is understood that the receiving area **1006**, the transition area **1010**, or other areas of the facility **1002** may be similarly equipped. Furthermore, the arrangement of the various areas within the facility **1002** is depicted functionally rather than schematically. For example, in some implementations, multiple different receiving areas **1006**, storage areas **1008**, and transition areas **1010** may be interspersed rather than segregated in the facility **1002**.

The facility **1002** may include, or be coupled to, the inventory management system **114**. The inventory management system **114** is configured to interact with one or more of the users **102** or devices such as sensors **106**, robots, material handling equipment, computing devices, and so forth, in one or more of the receiving area **1006**, the storage area **1008**, or the transition area **1010**.

During operation of the facility **1002**, the sensors **106** may be configured to provide sensor data **230**, or information based on the sensor data **230**, to the inventory management system **114**. The sensor data **230** may include the weight data, the capacitance data, the image data, and so forth. The sensors **106** are described in more detail below with regard to FIG. **11**.

The inventory management system **114** or other systems may use the sensor data **230** to track the location of objects within the facility **1002**, movement of the objects, or provide other functionality. Objects may include, but are not limited to, items **1004**, users **102**, totes **1014**, and so forth. For example, a series of images acquired by the image sensor **106**(**3**) may indicate removal by the user **102** of an item **1004** from a particular location on the fixture and placement of the item **1004** on or at least partially within the tote **1014**.

The facility **1002** may be configured to receive different kinds of items **1004** from various suppliers and to store them until a customer orders or retrieves one or more of the items **1004**. A general flow of items **1004** through the facility **1002** is indicated by the arrows of FIG. **10**. Specifically, as illustrated in this example, items **1004** may be received from one or more suppliers, such as manufacturers, distributors, wholesalers, and so forth, at the receiving area **1006**. In various implementations, the items **1004** may include mer-

chandise, commodities, perishables, or any suitable type of item **1004**, depending on the nature of the enterprise that operates the facility **1002**.

Upon being received from a supplier at the receiving area **1006**, the items **1004** may be prepared for storage in the storage area **1008**. For example, in some implementations, items **1004** may be unpacked or otherwise rearranged. The inventory management system **114** may include one or more software applications executing on a computer system to provide inventory management functions. These inventory management functions may include maintaining information indicative of the type, quantity, condition, cost, location, weight, or any other suitable parameters with respect to the items **1004**. The items **1004** may be stocked, managed, or dispensed in terms of countable units, individual units, or multiple units, such as packages, cartons, crates, pallets, or other suitable aggregations. Alternatively, some items **1004**, such as bulk products, commodities, and so forth, may be stored in continuous or arbitrarily divisible amounts that may not be inherently organized into countable units. Such items **1004** may be managed in terms of a measurable quantity such as units of length, area, volume, weight, time, duration, or other dimensional properties characterized by units of measurement. Generally speaking, a quantity of an item **1004** may refer to either a countable number of individual or aggregate units of an item **1004** or a measurable amount of an item **1004**, as appropriate.

After arriving through the receiving area **1006**, items **1004** may be stored within the storage area **1008**. In some implementations, like items **1004** may be stored or displayed together in the fixtures such as in bins, on shelves, hanging from pegboards, and so forth. For example, all items **1004** of a given kind are stored in one fixture. In other implementations, like items **1004** may be stored in different fixtures. For example, to optimize retrieval of certain items **1004** having frequent turnover within a large physical facility **1002**, those items **1004** may be stored in several different fixtures to reduce congestion that might occur at a single fixture.

When a customer order specifying one or more items **1004** is received, or as a user **102** progresses through the facility **1002**, the corresponding items **1004** may be selected or "picked" from the fixtures containing those items **1004**. In various implementations, item picking may range from manual to completely automated picking. For example, in one implementation, a user **102** may have a list of items **1004** they desire and may progress through the facility **1002** picking items **1004** from the fixtures within the storage area **1008** and placing those items **1004** into a tote **1014**. In other implementations, employees of the facility **1002** may pick items **1004** using written or electronic pick lists derived from customer orders. These picked items **1004** may be placed into the tote **1014** as the employee progresses through the facility **1002**.

After items **1004** have been picked, the items **1004** may be processed at the transition area **1010**. The transition area **1010** may be any designated area within the facility **1002** where items **1004** are transitioned from one location to another or from one entity to another. For example, the transition area **1010** may be a packing station within the facility **1002**. When the item **1004** arrives at the transition area **1010**, the item **1004** may be transitioned from the storage area **1008** to the packing station. Information about the transition may be maintained by the inventory management system **114**.

In another example, if the items **1004** are departing the facility **1002**, a list of the items **1004** may be obtained and used by the inventory management system **114** to transition responsibility for, or custody of, the items **1004** from the facility **1002** to another entity. For example, a carrier may accept the items **1004** for transport with that carrier accepting responsibility for the items **1004** indicated in the list. In another example, a user **102** may purchase or rent the items **1004** and remove the items **1004** from the facility **1002**. During use of the facility **1002**, the user **102** may move about the facility **1002** to perform various tasks, such as picking or placing the items **1004** in the fixtures.

The inventory management system **114** may generate the interaction data **146**. The interaction data **146** may be based at least in part on one or more of the tile output data **134**, the fixture data, and so forth. The interaction data **146** may provide information about an interaction, such as a pick of an item **1004** from the fixture, a place of an item **1004** to the fixture, a touch made to an item **1004** at the fixture, a gesture associated with an item **1004** at the fixture, and so forth. The interaction data **146** may include one or more of the type of interaction, duration of interaction, interaction location identifier indicative of where from the fixture the interaction took place, item identifier, quantity change to the item **1004**, user identifier, and so forth. The interaction data **146** may then be used to further update the item data. For example, the quantity of items **1004** on hand at a particular lane on the shelf may be changed based on an interaction that picks or places one or more items **1004**.

The inventory management system **114** may combine or otherwise utilize data from different sensors **106** of different types. For example, weight data obtained from weight sensors **106(2)** at the fixture may be used instead of, or in conjunction with, one or more of the capacitance data to determine the interaction data **146**.

FIG. **11** is a block diagram **1100** illustrating additional details of the facility **1002**, according to some implementations. The facility **1002** may be connected to one or more networks **1102**, which in turn connect to one or more servers **112**. The networks **1102** may include one or more of the first network **110**, the second network **132**, or other networks. The network **1102** may include private networks such as an institutional or personal intranet, public networks such as the Internet, or a combination thereof. The network **1102** may utilize wired technologies (e.g., wires, fiber optic cables, and so forth), wireless technologies (e.g., radio frequency, infrared, acoustic, optical, and so forth), or other connection technologies. The network **1102** is representative of any type of communication network, including one or more of data networks or voice networks. The network **1102** may be implemented using wired infrastructure (e.g., copper cable, fiber optic cable, and so forth), a wireless infrastructure (e.g., cellular, microwave, satellite, and so forth), or other connection technologies.

The servers **112** may be configured to execute one or more modules or software applications associated with the inventory management system **114** or other systems. While the servers **112** are illustrated as being in a location outside of the facility **1002**, in other implementations, at least a portion of the servers **112** may be located at the facility **1002**. The servers **112** are discussed in more detail below with regard to FIG. **12**.

The users **102**, the totes **1014**, or other objects in the facility **1002** may be equipped with one or more tags **1104**. The tags **1104** may be configured to emit a signal **1106**. In one implementation, the tag **1104** may be a RFID tag **1104** configured to emit an RF signal **1106** upon activation by an external signal. For example, the external signal may comprise a radio frequency signal or a magnetic field configured

to energize or activate the RFID tag **1104**. In another implementation, the tag **1104** may comprise a transmitter and a power source configured to power the transmitter. For example, the tag **1104** may comprise a Bluetooth Low Energy (BLE) transmitter and battery. In other implementations, the tag **1104** may use other techniques to indicate presence of the tag **1104**. For example, an acoustic tag **1104** may be configured to generate an ultrasonic signal **1106**, which is detected by corresponding acoustic receivers. In yet another implementation, the tag **1104** may be configured to emit an optical signal **1106**.

The inventory management system **114** may be configured to use the tags **1104** for one or more of identification of the object, determining a location of the object, and so forth. For example, the users **102** may wear tags **1104**, the totes **1014** may have tags **1104** affixed, and so forth, which may be read and, based at least in part on signal strength, used to determine identity and location. In other implementations, the users **102** may wear portable transmitters, the totes **1014** may be equipped with a portable receiver, portable transmitter, and so forth. In some implementations, the two methodologies may be combined, such as tags **1104** and the use of a portable transmitter.

Generally, the inventory management system **114** or other systems associated with the facility **1002** may include any number and combination of input components, output components, and servers **112**.

The one or more sensors **106** may be arranged at one or more locations within the facility **1002**. For example, the sensors **106** may be mounted on or within a floor, wall, at a ceiling, at fixture **1108**, on a tote **1014**, may be carried or worn by a user **102**, may be part of the portable device **104**, and so forth.

The sensors **106** may include one or more touch sensors **108**, such as described above. The touch sensors **108** may use resistive, capacitive, surface capacitance, projected capacitance, mutual capacitance, optical, acoustic, Interpolating Force-Sensitive Resistance (IFSR), or other mechanisms to determine the position of a touch or near-touch. For example, a force sensitive resistor may comprise a material configured to change electrical resistance responsive to an applied force. The location within the material of that change in electrical resistance may indicate the position of the touch. The inventory management system **114** may use the sensor data **230** acquired by the touch sensors **108** to receive information from the user **102**.

The sensors **106** may include one or more biometric sensors **106(1)**. For example, the biometric sensors **106(1)** may include fingerprint readers, iris cameras, facial recognition cameras, palmprint readers, electrocardiogram devices, and so forth.

The sensors **106** may include one or more weight sensors **106(2)** that are configured to measure the weight of a load, such as the item **1004**, the tote **1014**, or other objects. The weight sensors **106(2)** may be configured to measure the weight of the load at one or more of the fixtures **1108**, the tote **1014**, on the floor of the facility **1002**, and so forth. For example, the shelf may include a plurality of lanes or platforms, with one or more weight sensors **106(2)** beneath each one to provide weight sensor data about an individual lane or platform. The weight sensors **106(2)** may include one or more sensing mechanisms to determine the weight of a load. These sensing mechanisms may include piezoresistive devices, piezoelectric devices, capacitive devices, electromagnetic devices, optical devices, potentiometric devices, microelectromechanical devices, and so forth. The sensing mechanisms of weight sensors **106(2)** may operate as transducers that generate one or more signals based on an applied force, such as that of the load due to gravity. For example, the weight sensor **106(2)** may comprise a load cell having a strain gauge and a structural member that deforms slightly when weight is applied. By measuring a change in the electrical characteristic of the strain gauge, such as capacitance or resistance, the weight may be determined. In another example, the weight sensor **106(2)** may comprise a force sensing resistor (FSR). The FSR may comprise a resilient material that changes one or more electrical characteristics when compressed. For example, the electrical resistance of a particular portion of the FSR may decrease as the particular portion is compressed. The inventory management system **114** may use the data acquired by the weight sensors **106(2)** to identify an object, determine a change in the quantity of objects, determine a location of an object, maintain shipping records, and so forth.

The sensors **106** may include one or more image sensors **106(3)**. The one or more image sensors **106(3)** may include imaging sensors configured to acquire images of a scene. The image sensors **106(3)** are configured to detect light in one or more wavelengths including, but not limited to, terahertz, infrared, visible, ultraviolet, and so forth. The image sensors **106(3)** may comprise charge coupled devices (CCD), complementary metal oxide semiconductor (CMOS) devices, microbolometers, and so forth. The inventory management system **114** may use image data acquired by the image sensors **106(3)** during operation of the facility **1002**. For example, the inventory management system **114** may identify items **1004**, users **102**, totes **1014**, and so forth, based at least in part on their appearance within the image data acquired by the image sensors **106(3)**. The image sensors **106(3)** may be mounted in various locations within the facility **1002**. For example, image sensors **106(3)** may be mounted overhead, on the fixtures **1108**, may be worn or carried by users **102**, may be affixed to totes **1014**, and so forth.

One or more depth sensors **106(4)** may also be included in the sensors **106**. The depth sensors **106(4)** are configured to acquire spatial or three-dimensional (3D) data, such as depth information, about objects within a field of view (FOV). The depth sensors **106(4)** may include range cameras, lidar systems, sonar systems, radar systems, structured light systems, stereo vision systems, optical interferometry systems, and so forth. The inventory management system **114** may use the 3D data acquired by the depth sensors **106(4)** to identify objects, determine a location of an object in 3D real space, and so forth.

One or more buttons **106(5)** may be configured to accept input from the user **102**. The buttons **106(5)** may comprise mechanical, capacitive, optical, or other mechanisms. For example, the buttons **106(5)** may comprise mechanical switches configured to accept an applied force from a touch of the user **102** to generate an input signal. The inventory management system **114** may use data from the buttons **106(5)** to receive information from the user **102**. For example, the tote **1014** may be configured with a button **106(5)** to accept input from the user **102** and send information indicative of the input to the inventory management system **114**.

One or more microphones **106(6)** may be configured to acquire information indicative of sound present in the environment. In some implementations, arrays of microphones **106(6)** may be used. These arrays may implement beamforming techniques to provide for directionality of gain. The inventory management system **114** may use the one or more microphones **106(6)** to acquire information from acoustic

tags **1104**, accept voice input from the users **102**, determine ambient noise level, and so forth.

The sensors **106** may include one or more optical sensors **106(7)**. The optical sensors **106(7)** may be configured to provide data indicative of one or more of color or intensity of light impinging thereupon. For example, the optical sensor array **106(13)** may comprise a photodiode and associated circuitry configured to generate a signal or data indicative of an incident flux of photons. As described below, the optical sensor array **106(13)** may comprise a plurality of the optical sensors **106(7)**. For example, the optical sensor **106(7)** may comprise an array of ambient light sensors such as the ISL76683 as provided by Intersil Corporation of Milpitas, Calif., USA, or the MAX44009 as provided by Maxim Integrated of San Jose, Calif., USA. In other implementations, other optical sensors **106(7)** may be used. The optical sensors **106(7)** may be sensitive to one or more of infrared light, visible light, or ultraviolet light. For example, the optical sensors **106(7)** may be sensitive to infrared light, and infrared light sources such as light emitting diodes (LEDs) may provide illumination.

The optical sensors **106(7)** may include photodiodes, photoresistors, photovoltaic cells, quantum dot photoconductors, bolometers, pyroelectric infrared detectors, and so forth. For example, the optical sensor **106(7)** may use germanium photodiodes to detect infrared light.

One or more radio frequency identification (RFID) readers **106(8)**, near field communication (NFC) systems, and so forth, may be included as sensors **106**. For example, the RFID readers **106(8)** may be configured to read the RF tags **1104**. Information acquired by the RFID reader **106(8)** may be used by the inventory management system **114** to identify an object associated with the RF tag **1104** such as the item **1004**, the user **102**, the tote **1014**, and so forth. For example, based on information from the RFID readers **106(8)** detecting the RF tag **1104** at different times and RFID readers **106(8)** having different locations in the facility **1002**, a velocity of the RF tag **1104** may be determined. NFC readers may be configured to operate at a particular frequency, such as 13.56 MHz. In comparison, RFID readers **106(8)** may operate at various frequency ranges including 125-134 kHz, 13.56 MHz, or 856-960 MHz. Standards associated with the NFC reader and operation may be a subset of the standards associated with the RFID reader **106(8)**. NFC may also permit bidirectional communication between the devices, where RFID signals may be unidirectional.

One or more RF receivers **106(9)** may also be included as sensors **106**. In some implementations, the RF receivers **106(9)** may be part of transceiver assemblies. The RF receivers **106(9)** may be configured to acquire RF signals **1106** associated with Wi-Fi, Bluetooth, ZigBee, 4G, 3G, LTE, or other wireless data transmission technologies. The RF receivers **106(9)** may provide information associated with data transmitted via radio frequencies, signal strength of RF signals **1106**, and so forth. For example, information from the RF receivers **106(9)** may be used by the inventory management system **114** to determine a location of an RF source, such as a communication interface onboard the tote **1014**.

The sensors **106** may include one or more accelerometers **106(10)**, which may be worn or carried by the user **102**, mounted to the tote **1014**, and so forth. The accelerometers **106(10)** may provide information such as the direction and magnitude of an imposed acceleration. Data such as rate of acceleration, determination of changes in direction, speed, and so forth, may be determined using the accelerometers **106(10)**.

A gyroscope **106(11)** may provide information indicative of rotation of an object affixed thereto. For example, the tote **1014** or other objects may be equipped with a gyroscope **106(11)** to provide data indicative of a change in orientation of the object.

A magnetometer **106(12)** may be used to determine an orientation by measuring ambient magnetic fields, such as the terrestrial magnetic field. The magnetometer **106(12)** may be worn or carried by the user **102**, mounted to the tote **1014**, and so forth. For example, the magnetometer **106(12)** mounted to the tote **1014** may act as a compass and provide information indicative of which direction the tote **1014** is oriented.

An optical sensor array **106(13)** may comprise one or more optical sensors **106(7)**. The optical sensors **106(7)** may be arranged in a regular, repeating, or periodic two-dimensional arrangement such as a grid. The optical sensor array **106(13)** may generate image data. For example, the optical sensor array **106(13)** may be arranged within or below fixture **1108** and obtain information about shadows of items **1004**, hand of the user **102**, and so forth.

The sensors **106** may include proximity sensors **106(14)** used to determine presence of an object, such as the user **102**, the tote **1014**, and so forth. The proximity sensors **106(14)** may use optical, electrical, ultrasonic, electromagnetic, or other techniques to determine a presence of an object. In some implementations, the proximity sensors **106(14)** may use an optical emitter and an optical detector to determine proximity. For example, an optical emitter may emit light, a portion of which may then be reflected by the object back to the optical detector to provide an indication that the object is proximate to the proximity sensor **106(14)**. In other implementations, the proximity sensors **106(14)** may comprise a capacitive proximity sensor **106(14)** configured to provide an electrical field and determine a change in electrical capacitance due to presence or absence of an object within the electrical field.

The proximity sensors **106(14)** may be configured to provide sensor data indicative of one or more of a presence or absence of an object, a distance to the object, or characteristics of the object. An optical proximity sensor **106(14)** may use time-of-flight (ToF), structured light, interferometry, or other techniques to generate distance data. For example, ToF determines a propagation time (or "round-trip" time) of a pulse of emitted light from an optical emitter or illuminator that is reflected or otherwise returned to an optical detector. By dividing the propagation time in half and multiplying the result by the speed of light in air, the distance to an object may be determined. In another implementation, a structured light pattern may be provided by the optical emitter. A portion of the structured light pattern may then be detected on the object using a sensor **106** such as an image sensor **106(3)**. Based on an apparent distance between the features of the structured light pattern, the distance to the object may be calculated. Other techniques may also be used to determine distance to the object. In another example, the color of the reflected light may be used to characterize the object, such as skin, clothing, tote **1014**, and so forth.

The sensors **106** may also include an instrumented auto-facing unit (IAFU) **106(15)**. The IAFU **106(15)** may comprise a position sensor configured to provide data indicative of displacement of a pusher. As an item **1004** is removed from the IAFU **106(15)**, the pusher moves, such as under the influence of a spring, and pushes the remaining items **1004** in the IAFU **106(15)** to the front of the fixture **1108**. By using data from the position sensor, and given item data such as a depth of an individual item **1004**, a count may be

determined, based on a change in position data. For example, if each item **1004** is 1 inch deep, and the position data indicates a change of 17 inches, the quantity held by the IAFU **106**(**15**) may have changed by 17 items **1004**. This count information may be used to confirm or provide a cross check for a count obtained by other means, such as analysis of the weight data, the capacitance data, the image data, and so forth.

The sensors **106** may include other sensors **106**(S) as well. For example, the other sensors **106**(S) may include light curtains, ultrasonic rangefinders, thermometers, barometric sensors, air pressure sensors, hygrometers, and so forth. For example, the inventory management system **114** may use information acquired from thermometers and hygrometers in the facility **1002** to direct the user **102** to check on delicate items **1004** stored in a particular fixture **1108**, which is overheating, too dry, too damp, and so forth.

In some implementations, the image sensor **106**(**3**) or other sensors **106**(S) may include hardware processors, memory, and other elements configured to perform various functions. For example, the image sensors **106**(**3**) may be configured to generate image data, send the image data to another device such as the servers **112**, and so forth.

The facility **1002** may include one or more access points **1110** configured to establish one or more wireless networks. The access points **1110** may use Wi-Fi, NFC, Bluetooth, or other technologies to establish wireless communications between a device and the network **1102**. The wireless networks allow devices to communicate with one or more of the sensors **106**, the inventory management system **114**, the optical sensor arrays **106**(**13**), the tag **1104**, a communication device of the tote **1014**, or other devices.

Output devices **218** may also be provided in the facility **1002**. The output devices **218** are configured to generate signals, which may be perceived by the user **102** or detected by the sensors **106**. In some implementations, the output devices **218** may be used to provide illumination of the optical sensor array **106**(**13**).

Haptic output devices **218**(**1**) are configured to provide a signal that results in a tactile sensation to the user **102**. The haptic output devices **218**(**1**) may use one or more mechanisms such as electrical stimulation or mechanical displacement to provide the signal. For example, the haptic output devices **218**(**1**) may be configured to generate a modulated electrical signal, which produces an apparent tactile sensation in one or more fingers **302** of the user **102**. In another example, the haptic output devices **218**(**1**) may comprise piezoelectric or rotary motor devices configured to provide a vibration, which may be felt by the user **102**.

One or more audio output devices **218**(**2**) may be configured to provide acoustic output. The acoustic output includes one or more of infrasonic sound, audible sound, or ultrasonic sound. The audio output devices **218**(**2**) may use one or more mechanisms to generate the acoustic output. These mechanisms may include, but are not limited to, the following: voice coils, piezoelectric elements, magnetostrictive elements, electrostatic elements, and so forth. For example, a piezoelectric buzzer or a speaker may be used to provide acoustic output.

The display devices **312** may be configured to provide output, which may be seen by the user **102** or detected by a light-sensitive sensor such as an image sensor **106**(**3**) or an optical sensor **106**(**7**). In some implementations, the display devices **312** may be configured to produce output in one or more of infrared, visible, or ultraviolet light. The output may be monochrome or in color. The display devices **312** may be one or more of emissive, reflective, microelectromechanical, and so forth. An emissive display device **312**, such as using LEDs, is configured to emit light during operation. In comparison, a reflective display device **312**, such as using an electrophoretic element, relies on ambient light to present an image. Backlights or front lights may be used to illuminate non-emissive display devices **312** to provide visibility of the output in conditions where the ambient light levels are low.

The display devices **312** may be located at various points within the facility **1002**. For example, the addressable display devices **312** may be located on the fixtures **1108**, totes **1014**, on the floor of the facility **1002**, and so forth.

Other output devices **218**(P) may also be present. For example, the other output devices **218**(P) may include scent/odor dispensers, document printers, 3D printers or fabrication equipment, and so forth.

FIG. **12** illustrates a block diagram **1200** of a server **112** configured to support operation of the facility **1002**, according to some implementations. The servers **112** may be physically present at the facility **1002**, may be accessible by the network **1102**, or a combination of both. The server **112** does not require end-user knowledge of the physical location and configuration of the system that delivers the services. Common expressions associated with the servers **112** may include "on-demand computing", "software as a service (SaaS)", "platform computing", "network-accessible platform", "cloud services", "data centers", and so forth. Services provided by the servers **112** may be distributed across one or more physical or virtual devices.

One or more power supplies **1202** may be configured to provide electrical power suitable for operating the components in the servers **112**. The one or more power supplies **1202** may comprise batteries, capacitors, fuel cells, photovoltaic cells, wireless power receivers, conductive couplings suitable for attachment to an external power source such as provided by an electric utility, and so forth. The servers **112** may include one or more hardware processors **1204** (processors) configured to execute one or more stored instructions. The processors **1204** may comprise one or more cores. One or more clocks **1206** may provide information indicative of date, time, ticks, and so forth. For example, the processor **1204** may use data from the clock **1206** to associate a particular interaction with a particular point in time.

The servers **112** may include one or more communication interfaces **1208** such as input/output (I/O) interfaces **1210**, network interfaces **1212**, and so forth. The communication interfaces **1208** enable the servers **112**, or components thereof, to communicate with other devices or components. The communication interfaces **1208** may include one or more I/O interfaces **1210**. The I/O interfaces **1210** may comprise Inter-Integrated Circuit (I2C), Serial Peripheral Interface bus (SPI), Universal Serial Bus (USB) as promulgated by the USB Implementers Forum, RS-232, and so forth.

The I/O interface(s) **1210** may couple to one or more I/O devices **1214**. The I/O devices **1214** may include input devices such as one or more of a sensor **106**, keyboard, mouse, scanner, and so forth. The I/O devices **1214** may also include output devices **218** such as one or more of a display device **312**, printer, audio speakers, and so forth. In some embodiments, the I/O devices **1214** may be physically incorporated with the servers **112** or may be externally placed.

The network interfaces **1212** may be configured to provide communications between the servers **112** and other devices, such as the SFTs **128**, totes **1014**, routers, access points **1110**, and so forth. The network interfaces **1212** may

include devices configured to couple to personal area networks (PANs), local area networks (LANs), wireless local area networks (WLANS), wide area networks (WANs), and so forth. For example, the network interfaces **1212** may include devices compatible with Ethernet, Wi-Fi, Bluetooth, ZigBee, and so forth.

The servers **112** may also include one or more busses or other internal communications hardware or software that allow for the transfer of data between the various modules and components of the servers **112**.

As shown in FIG. **12**, the servers **112** includes one or more memories **1216**. The memory **1216** may comprise one or more non-transitory CRSM. The memory **1216** provides storage of computer-readable instructions, data structures, program modules, and other data for the operation of the servers **112**. A few example functional modules are shown stored in the memory **1216**, although the same functionality may alternatively be implemented in hardware, firmware, or as a system on a chip (SoC).

The memory **1216** may include at least one operating system (OS) module **1218**. The OS module **1218** is configured to manage hardware resource devices such as the I/O interfaces **1210**, the I/O devices **1214**, the communication interfaces **1208**, and provide various services to applications or modules executing on the processors **1204**. The OS module **1218** may implement a variant of the FreeBSD operating system as promulgated by the FreeBSD Project; other UNIX or UNIX-like variants; a variation of the Linux operating system as promulgated by Linus Torvalds; the Windows operating system from Microsoft Corporation of Redmond, Wash., USA; and so forth.

Also stored in the memory **1216** may be a data store **1220** and one or more of the following modules. These modules may be executed as foreground applications, background tasks, daemons, and so forth. The data store **1220** may use a flat file, database, linked list, tree, executable code, script, or other data structure to store information. In some implementations, the data store **1220** or a portion of the data store **1220** may be distributed across one or more other devices including the servers **112**, network attached storage devices, and so forth.

A communication module **1222** may be configured to establish communications with one or more of the totes **1014**, sensors **106**, display devices **312**, other servers **112**, or other devices. The communications may be authenticated, encrypted, and so forth.

The memory **1216** may store an inventory management module **1224**. The inventory management module **1224** is configured to provide the inventory functions as described herein with regard to the inventory management system **114**. For example, the inventory management module **1224** may track items **1004** between different fixtures **1108**, to and from the totes **1014**, and so forth.

The inventory management module **1224** may include one or more of a data acquisition module **1226**, a tracking module **138**, an analysis module **142**, an action module **1228**, and so forth. The data acquisition module **1226** may be configured to acquire and access information associated with operation of the facility **1002**. For example, the data acquisition module **1226** may be configured to acquire tile output data **134** from the SFTs **128**, fixture data, sensor data **230** such as the time series data **316**, weight data, capacitance data, image data, and so forth. The sensor data **230** may be accessed by the other modules for use.

The data store **1220** may also store item data **1230**. The item data **1230** provides information about a particular type of item **1004**, including characteristics of that type of item **1004** such as physical dimensions, where that type of item **1004** is located in the facility **1002**, characteristics about how the item **1004** appears, capacitance values associated with the type of item **1004**, attenuation characteristics of an EMS **122**, and so forth. For example, the item data **1230** may indicate that the type of item **1004** is "Bob's Low Fat Baked Beans, 10 oz can" with a stock keeping unit number of "24076513". The item data **1230** may indicate the types and quantities of items **1004** that are expected to be stored at that particular fixture **1108** such as in a particular lane on a shelf, width and depth of that type of item **1004**, weight of the item **1004** individually or in aggregate, sample images of the type of item **1004**, and so forth.

The item data **1230** may include an item identifier. The item identifier may be used to distinguish one type of item **1004** from another. For example, the item identifier may include a stock keeping unit (SKU) string, Universal Product Code (UPC) number, radio frequency identification (RFID) tag data, and so forth. The items **1004** that are of the same type may be referred to by the same item identifier. For example, cans of beef flavor Brand X dog food may be represented by the item identifier value of "9811901181". In other implementations, non-fungible items **1004** may each be provided with a unique item identifier, allowing each to be distinguished from one another.

The item data **1230** may include one or more of geometry data, item weight data, sample image data, sample capacitance data, or other data. The geometry data may include information indicative of size and shape of the item **1004** in one-, two-, or three-dimensions. For example, the geometry data may include the overall shape of an item **1004**, such as a cuboid, sphere, cylinder, and so forth. The geometry data may also include information such as length, width, depth, and so forth, of the item **1004**. Dimensional information in the geometry data may be measured in pixels, centimeters, inches, arbitrary units, and so forth. The geometry data may be for a single item **1004**, or a package, kit, or other grouping considered to be a single item **1004**.

The item weight data comprises information indicative of a weight of a single item **1004**, or a package, kit, or another grouping considered to be a single item **1004**. The item data **1230** may include other data. For example, the other data may comprise weight distribution of the item **1004**, point cloud data for the item **1004**, and so forth.

The sample capacitance data may comprise data indicative of a previously measured or calculated change in capacitance obtained by a representative capacitive sensor **106** based on the presence or absence of a sample of the type of item **1004**. For example, during processing or intake of the item **1004** at the facility **1002**, a sample of the type of item **1004** may be placed on a capacitive sensor **106** to generate the sample capacitance data. Similar data may be obtained for the attenuation or propagation of the EMS **122** across the item **1004**.

The sample image data may comprise one or more images of one or more of that type of item **1004**. For example, sample image data may be obtained during processing or intake of the item **1004** to be used by the facility **1002**.

The item data **1230** may include one or more fixture identifiers (IDs). The fixture ID is indicative of a particular area or volume of fixture **1108** such as a shelf that is designated for stowage of the type of item **1004**. For example, a single shelf may have several lanes, each with a different fixture ID. Each of the different fixture IDs may be associated with a lane having a particular area on the shelf designated for storage of a particular type of item **1004**. A single type of item **1004** may be associated with a particular

fixture ID, a plurality of fixture IDs may be associated with the single type of item **1004**, more than one type of item **1004** may be associated with the particular fixture ID, and so forth.

The item data **1230** may also include quantity data. The quantity data may comprise a count or value indicative of a number of items **1004**. The count may be a measured or an estimated value. The quantity data may be associated with a particular fixture ID, for an entire facility **1002**, and so forth. For example, the same type of item **1004** may be stored at different shelves within the facility **1002**. The quantity data may indicate the quantity on hand for each of the different fixtures **1108**.

The tracking module **138** may access physical layout data **1232** and generate tracking data **140**. The tracking module **138** may be configured to determine a location within the facility **1002** of the user **102** who is associated with a particular user account as specified in the account data **118** as determined by the authentication module **116**. For example, the tracking module **138** may determine that an item **1004** has been removed from a lane and placed into the tote **1014** based on the fixture data indicative of the user's **102** characteristic data **136** having been received at the lane. The tracking module **138** may then determine that the tote **1014** is associated with the account data **118** indicated by the authentication module **116** that is representative of the user **102**. Based on this information, the analysis module **142** may generate the interaction data **146**.

The analysis module **142** may utilize the tile output data **134**, information from the authentication module **116**, fixture data, weight data, capacitance data, item data **1230**, and other information to generate interaction data **146**. The interaction data **146** is indicative of action such as picking or placing an item **1002** for a particular fixture **1108**, presence of the user **102** at the fixture **1108**, and so forth.

The inventory management module **1224**, and modules associated therewith, may access sensor data **230**, threshold data **1234**, and so forth. The threshold data **1234** may comprise one or more thresholds, ranges, percentages, and so forth, that may be used by the various modules in operation.

In some implementations, the analysis module **142** may generate output data **1236**. For example, the output data **1236** may include the interaction data **146**, inventory levels for individual types of items **1002**, overall inventory, and so forth. The analysis module **142** may determine if the user **102** is standing, moving, lying on the floor, and so forth. For example, the analysis module **142** may determine an area of contact with the floor based on the tile output data **134**. If the area of contact exceeds a threshold value, the user **102** may be determined to be lying on the floor. Based on this determination, other actions may be taken. For example, alarm data may be generated to summon assistance if a user **102** is deemed to be lying on the floor.

The inventory management module **1224** may utilize the physical layout data **1232**. The physical layout data **1232** may provide information indicative of location of the SFTs **128**, where sensors **106** and the fixtures **1108** are in the facility **1002** with respect to one another, FOV of sensors **106** relative to the fixture **1108**, and so forth. For example, the physical layout data **1232** may comprise information representative of a map or floor plan of the facility **1102** with relative positions of the fixtures **1108**, location of individual SFTs **128** therein, arrangements of the segments, planogram data indicative of how items **1004** are to be arranged at the fixtures **1108**, and so forth. Continuing the example, the physical layout data **1232** may be based on using the relative arrangement of the SFTs **128** in conjunction with their physical dimensions to specify where the SFTs **128** are placed within the facility **1002**.

The physical layout data **1232** may associate a particular fixture ID with other information such as physical location data, sensor position data, sensor direction data, sensor identifiers, and so forth. The physical layout data **1232** provides information about where in the facility **1002** objects are, such as the fixtures **1108**, the sensors **106**, and so forth. In some implementations, the physical location data **1232** may be relative to another object. For example, the physical location data **1232** may indicate that a particular weight sensor **106(2)**, capacitive sensor **106**, or image sensor **106(3)** is associated with the shelf or portion thereof.

The inventory management module **1224** may utilize the physical layout data **1232** and other information during operation. For example, the tracking module **138** may utilize physical layout data **1232** to determine what capacitance data acquired from particular capacitive sensors **106** corresponds to a particular shelf, lane, or other fixture **1108**.

The tracking module **138** may access information from sensors **106** within the facility **1002**, such as those at the shelf or other fixtures **1108**, onboard the tote **1014**, carried by or worn by the user **102**, and so forth. For example, the tracking module **138** may receive the fixture data and use the characteristic data **136** to associate a particular user **102** with a pick or place of an item **1004** at the associated fixture **1108**.

The account item data **1238** may also be included in the data store **1220** and comprises information indicative of one or more items **1004** that are within the custody of a particular user **102**, within a particular tote **1014**, and so forth. For example, the account item data **1238** may comprise a list of the contents of the tote **1014**. Continuing the example, the list may be further associated with the user account determined by the authentication module **116** that is representative of the user **102**. In another example, the account item data **1238** may comprise a list of items **1004** that the user **102** is carrying. The tracking module **138** may use the account item data **1238** to determine subsets of possible items **1004** with which the user **102** may have interacted.

The action module **1228** may be configured to initiate or coordinate one or more actions responsive to output data **1236**. For example, the action module **1228** may access output data **1236** that indicates a particular fixture **1108** is empty and in need of restocking. An action such as a dispatch of a work order or transmitting instructions to a robot may be performed to facilitate restocking of the fixture **1108**.

Processing sensor data **230**, such as the image data, may be performed by a module implementing, at least in part, one or more of the following tools or techniques. In one implementation, processing of the image data may be performed, at least in part, using one or more tools available in the OpenCV library as developed by Intel Corporation of Santa Clara, Calif., USA; Willow Garage of Menlo Park, Calif., USA; and Itseez of Nizhny Novgorod, Russia, with information available at www.opencv.org. In another implementation, functions available in the OKAO machine vision library as promulgated by Omron Corporation of Kyoto, Japan, may be used to process the sensor data **230**. In still another implementation, functions such as those in the Machine Vision Toolbox for Matlab (MVTB) available using MATLAB as developed by Math Works, Inc. of Natick, Mass., USA, may be utilized.

Techniques such as artificial neural networks (ANNs), active appearance models (AAMs), active shape models (ASMs), principal component analysis (PCA), cascade clas-

sifiers, and so forth, may also be used to process the sensor data **230** or other data. For example, the ANN may be a trained using a supervised learning algorithm such that object identifiers are associated with images of particular objects within training images provided to the ANN. Once trained, the ANN may be provided with the sensor data **230** and the item data **1230** to allow for a determination of similarity between two or more images.

The sensor data **230** obtained from different sensors **106** may be used to compare or validate output data **1236**. For example, the image data may indicate the presence of a person based on a coat or jacket that is arranged across the back of a chair. However, the tile output data **134** provides information that no user **102** is currently present at that location in the facility **1002**. This difference may be used to generate an alarm, notify an associate in the facility **1002**, and so forth.

Other data **1240** may be stored in the data store **1220** as well as other modules **1242** in the memory **1216**. For example, the other modules **1242** may include a billing module while the other data **1240** may include billing data.

The system described above may be utilized in a variety of different settings including, but not limited to, commercial, non-commercial, medical, and so forth. For example, the portable device **104** and the SFTs **128** may be deployed in a home, hospital, care facility, correctional facility, transportation facility, office, and so forth. The authentication module **116** may be used to identify particular users **102**. The tracking module **138** may provide tracking data **140**, such as the location of these identified users **102** within a facility. The analysis module **142** may be used to generate output data **1236** that is indicative of a status of the user **102**, such as whether the user **102** is standing, sitting, lying on the floor, and so forth.

The processes discussed in this disclosure may be implemented in hardware, software, or a combination thereof. In the context of software, the described operations represent computer-executable instructions stored on one or more computer-readable storage media that, when executed by one or more hardware processors, perform the recited operations. Generally, computer-executable instructions include routines, programs, objects, components, data structures, and the like that perform particular functions or implement particular abstract data types. Those having ordinary skill in the art will readily recognize that certain steps or operations illustrated in the figures above may be eliminated, combined, or performed in an alternate order. Any steps or operations may be performed serially or in parallel. Furthermore, the order in which the operations are described is not intended to be construed as a limitation.

Embodiments may be provided as a software program or computer program product including a non-transitory computer-readable storage medium having stored thereon instructions (in compressed or uncompressed form) that may be used to program a computer (or other electronic device) to perform processes or methods described herein. The computer-readable storage medium may be one or more of an electronic storage medium, a magnetic storage medium, an optical storage medium, a quantum storage medium, and so forth. For example, the computer-readable storage media may include, but is not limited to, hard drives, floppy diskettes, optical disks, read-only memories (ROMs), random access memories (RAMs), erasable programmable ROMs (EPROMs), electrically erasable programmable ROMs (EEPROMs), flash memory, magnetic or optical cards, solid-state memory devices, or other types of physical media suitable for storing electronic instructions. Further, embodiments may also be provided as a computer program product including a transitory machine-readable signal (in compressed or uncompressed form). Examples of transitory machine-readable signals, whether modulated using a carrier or unmodulated, include, but are not limited to, signals that a computer system or machine hosting or running a computer program can be configured to access, including signals transferred by one or more networks. For example, the transitory machine-readable signal may comprise transmission of software by the Internet.

Separate instances of these programs can be executed on or distributed across any number of separate computer systems. Thus, although certain steps have been described as being performed by certain devices, software programs, processes, or entities, this need not be the case, and a variety of alternative implementations will be understood by those having ordinary skill in the art.

Additionally, those having ordinary skill in the art will readily recognize that the techniques described above can be utilized in a variety of devices, environments, and situations. Although the subject matter has been described in language specific to structural features or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as illustrative forms of implementing the claims.

What is claimed is:

1. A system comprising:

a portable device comprising:

a display device;

a touch sensor comprising:

electrodes configured to capacitively couple to a first portion of a user, and

capacitive sensor circuitry configured to apply a voltage to particular electrodes at particular times;

a first memory storing first computer-executable instructions; and

a first hardware processor to execute the first computer-executable instructions to:

access authentication data; and

control the capacitive sensor circuitry to generate a first signal at a first frequency that is propagated by a body of the user from the first portion of the user coupled to the electrodes to a second portion of the user coupled to a smart floor tile, wherein the first signal conveys the authentication data, and wherein the first signal is generated by changing from a first time to a second time the voltage applied to the particular electrodes; and

the smart floor tile comprising:

a receiver connected to a first antenna;

a transmitter to generate a second signal;

a second antenna coupled to the transmitter to radiate the second signal;

a communication interface;

a second memory storing second computer-executable instructions; and

a second hardware processor to execute the second computer-executable instructions to:

receive the first signal using the receiver;

analyze the first signal to determine the authentication data; and

send the authentication data using the communication interface.

2. The system of claim **1**, the smart floor tile further comprising:

the second memory storing third computer-executable instructions; and

the second hardware processor to further execute the third computer-executable instructions to:

configure the transmitter to modulate the second signal to convey data; and

the portable device further comprising:

the first memory storing fourth computer-executable instructions; and

the first hardware processor to further execute the fourth computer-executable instructions to:

determine time series data indicative of a time series of changes in capacitance as measured at one or more of the electrodes, wherein the changes are responsive to the second signal; and

determine the data based on the time series data.

3. The system of claim **1**, the touch sensor further comprising an oscillator to generate the voltage as an alternating current with the first frequency of between 10 kilohertz and 15 megahertz.

4. A system comprising:

a portable device comprising:

a touch sensor comprising:

electrodes configured to capacitively couple to a first portion of a user; and

touch sensor circuitry configured to control application of a voltage to one or more of the electrodes;

a first memory storing first computer-executable instructions; and

a first hardware processor to execute the first computer-executable instructions to:

access authentication data; and

operate, at a first time, the touch sensor circuitry to generate a first signal with the one or more of the electrodes at a first frequency that is propagated by a body of the user from the first portion of the user coupled to the electrodes to a second portion of the user coupled to a smart floor tile, wherein the first signal conveys the authentication data; and

the smart floor tile comprising:

a receiver connected to an antenna;

a transmitter to generate a second signal;

the antenna coupled to the transmitter, the antenna configured to radiate the second signal;

a second memory storing second computer-executable instructions; and

a second hardware processor to execute the second computer-executable instructions to:

receive the first signal using the receiver; and

analyze the first signal to determine the authentication data.

5. The system of claim **4**, the first memory storing third computer- executable instructions; and

the first hardware processor to further execute the third computer-executable instructions to:

receive user input data using the touch sensor; and

generate the authentication data based on the user input data.

6. The system of claim **4**, the portable device further comprising:

one or more sensors;

the first memory storing third computer-executable instructions; and

the first hardware processor to further execute the third computer-executable instructions to:

acquire, using the one or more sensors, biometric data associated with the user; and

generate the authentication data based at least in part on the biometric data.

7. The system of claim **6**, the one or more sensors comprising one or more of:

a fingerprint scanner,

a palmprint scanner,

a camera,

a radio frequency identification (RFID) tag reader,

a near field communication (NFC) tag reader, or

a microphone.

8. The system of claim **4**, further comprising the first memory storing third computer-executable instructions; and

the first hardware processor to further execute the third computer-executable instructions to:

operate, at a second time, the touch sensor circuitry to determine time series data indicative of a time series of changes in one or more electrical characteristics at the one or more of the electrodes; and

analyze the time series data to generate data.

9. The system of claim **8**, wherein the one or more electrical characteristics comprise one or more of electrical resistance, electrical capacitance, frequency, or phase.

10. The system of claim **4**, the portable device further comprising one or more of:

a smart phone,

a wearable computing device, or

a tablet computer.

11. The system of claim **4**, the smart floor tile further comprising:

a communication interface; and

the second hardware processor to further execute the second computer-executable instructions to:

send the authentication data using the communication interface.

12. The system of claim **11**, the smart floor tile further comprising:

the second memory storing third computer-executable instructions; and

the second hardware processor to further execute the third computer-executable instructions to:

configure the transmitter to modulate the second signal to convey data; and

the portable device further comprising:

the first memory storing fourth computer-executable instructions; and

the first hardware processor to further execute the fourth computer-executable instructions to:

determine sensor data indicative of one or more changes in one or more electrical characteristics measured at the one or more of the electrodes in the touch sensor, wherein at least a portion of the one or more changes are responsive to the second signal; and determine the data based on the sensor data.

13. The system of claim **11**, wherein the first frequency operates at less than 15 megahertz.

14. The system of claim **4**, the touch sensor further comprising one or more of:

electrically capacitive junctions formed by two or more of the electrodes, or

electrically resistive junctions formed by the two or more of the electrodes.

15. A system comprising:

a portable device comprising:

a first device comprising a display device, the first device configurable to generate a signal and couple at least a portion of the signal to a first portion of a user;

a first memory storing first computer-executable instructions; and

a first hardware processor to execute the first computer-executable instructions to:

access authentication data; and

operate the first device to generate a first signal at a first frequency that is propagated by a body of the user from the first portion of the user coupled to the first device to a second portion of the user coupled to a smart floor tile, wherein the first signal conveys the authentication data; and

the smart floor tile comprising:

a receiver;

a second memory storing second computer-executable instructions; and

a second hardware processor to execute the second computer-executable instructions to:

receive the first signal using the receiver; and

determine the authentication data.

16. The system of claim **15**, wherein the display device is operated to change a voltage applied to one or more junctions therein to generate the first signal.

17. The system of claim **15**, wherein the first device further comprises a touch sensor, and further wherein the touch sensor is operated to change a voltage applied to one or more electrodes in the touch sensor to generate the first signal.

18. The system of claim **15**, wherein the first device further comprises a touch sensor;

the first memory storing third computer-executable instructions; and

the first hardware processor to further execute the third computer-executable instructions to:

operate the touch sensor to determine time series data indicative of a time series of changes in one or more electrical characteristics at one or more electrodes in the touch sensor; and

determine second data based on the time series data.

19. The system of claim **15**, wherein the first device further comprises a transmitter and an antenna coupled to the transmitter, and further wherein the transmitter is configured to generate the first signal having a carrier frequency of between 20 kilohertz and 15 megahertz.

20. The system of claim **15**, the portable device further comprising one or more sensors, the one or more sensors comprising one or more of:

a fingerprint scanner,

a palmprint scanner,

a camera,

a radio frequency identification (RFID) tag reader,

a near field communication (NFC) tag reader, or

a microphone;

the first memory storing third computer-executable instructions; and

the first hardware processor to further execute the third computer-executable instructions to:

acquire, using the one or more sensors, biometric data associated with the user; and

generate the authentication data based at least in part on the biometric data.

21. A system comprising:

a portable device comprising:

one or more sensors;

a device;

a first memory storing first computer-executable instructions; and

a first hardware processor to execute the first computer-executable instructions to:

acquire, using the one or more sensors, data associated with a user;

determine authentication data for the user based at least in part on the data associated with the user;

operate the device to generate a signal, wherein the signal conveys the authentication data for the user;

couple the signal to the user; and

propagate the signal to a smart floor tile via a path that incorporates the user; and

the smart floor tile comprising:

a second memory storing second computer-executable instructions; and

a second hardware processor to execute the second computer-executable instructions to:

receive the signal; and

determine the authentication data for the user.

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